THE FUNDAMENTALS OF PSYCHOLOGY

W. B. PILLSBURY

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PREFACE

In this third edition of *The Fundamentals of Psychology*, the general purpose of the preceding editions has been adhered to — that of presenting an impartial statement of the more important facts of the science. There must be selection both in points of view and in the facts that are given. The field has grown too large to be covered in a year, if all details are to be incorporated. Selection must be made of the facts that have the most general bearing and of the points of view that can be most readily organized into a consistent system; a sane and not too colorless eclecticism has been striven for. It is probably a favorable time to give an impartial view, for most of the very rigid systems seem to be undergoing change or losing their appeal. Emphasis has been placed upon the points in the different interpretations that are common to most schools.

In the arrangement of material the plan of treating the nervous processes rather fully first has been retained. I have found that these facts are needed in discussing the more psychological principles, and that it is best to state them before they are to be used, rather than to refer ahead to the facts as stated in later chapters. The objection that the student often finds them difficult has not seemed to me a sufficient reason for postponing them.

I have begun the discussion of the more strictly psychological processes with the individual differences for they again are to be used later. Then the motor and affective activities have been considered. These constitute a consistent whole. In treating the intellectual or cognitive processes, I have retained the plan of considering first the more fundamental activities that are common to all of the more concrete processes, and then passing on to the different concrete activities. The three fundamental processes are the recall of older experiences, the general facts of the selection of sensory stimuli, and meaning and generalization. Meaning or reference is considered alone because of its importance for perception and abstract thinking, and because it makes possible an understanding of the new point of view introduced by the Gestalt school.

After these general factors are considered, perception, memory, and reasoning, which involve all of them, are taken up. On the whole this arrangement seems more satisfactory than to treat in one chapter all of the facts of recall, or of the reception and reaction upon stimulation. The latter procedure would require constant anticipation of principles not yet stated, which has always proved more confusing than to draw a distinction between the general and the particular processes.

The recognition of new results has considerably expanded the scope of the book. Not only have new detailed facts been introduced liberally, but new points of view have received much consideration. On many topics the facts and the interpretations are so closely interwoven that the facts cannot be presented without considering the point of view of the investigator. In consequence, results have been related to the different schools of thought, and opposing opinions presented with the factual material. This recognition of different attitudes has been emphasized still more by giving a brief statement of the schools important today, with a slight historical sketch of the backgrounds from which they have developed. The aim of the author has been to maintain a catholic point of view towards differences of opinion without being indifferent. It is hoped that the work offers a complete resumé of the facts of present-day psychology and an unprejudiced presentation of the divergent general theories.

It is my pleasure to acknowledge my indebtedness to many individuals for aid. Most of all I desire to thank my wife for very competent aid with the proof. Professor Griffitts supplied the material for the scatter diagram in Chapter VI, and many of my colleagues at the University of Michigan have given suggestions, consciously or unconsciously, that have been most useful. I express my gratitude to all.

I have borrowed extensively for cuts. I desire to thank Professor Ranson and W. B. Saunders Co. for permission to use a cut for Figure 33; Professor Gates and the Macmillan Co. for Figures 81 and 114; the Macmillan Co. for the use of Figure 38, from Luciani's Human Physiology; and Professor Terman and the Houghton Mifflin Co. for permission to reproduce tests for ages three and nine of the Terman Scale.

W. B. PILLSBURY.

ANN ARBOR, MICH.
March, 1934.

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CHAPTER I

INTRODUCTION

Psychology may be defined as the science which deals with man's behavior. The psychologist attempts to explain behavior in all of its phases, complex as well as simple. The aim of this presentation is to explain behavior as it is appreciated by the man himself as well as by the onlooker. Psychology like any other science is primarily interested in facts. The facts about behavior develop from two sides. They can be observed by another man and recorded by him. They can also be studied from within by the man who acts. The two points of view give approximately the same set of facts, but the facts take on a different appearance corresponding to the standpoint from which they are observed. On the one side we have merely gross physical movements and the changes that they work in the position of objects. From the other the movement is only an incident in a chain of experiences. In some cases the movement is preceded by a series of what we call ideas that foreshadow it. In other cases it comes without any warning and seems to have no special relation to the preceding events in the series.

Groups of experiences that precede in the awareness of the man who acts we call ideas or sensations. They are sensations when they are due to changes in the external world directly, as can be determined by the preceding events in the same series. They are ideas when they arise without such external stimuli, but follow laws of their own within the observer himself. Understanding the movement from within consists in relating it to the preceding ideas and sensations and determining whether there be any causal connection between them. Understanding from without must be in terms of the stimuli that precede the movement. One must infer from the regularity of the succession whether this and this alone is the true cause of response.

Appreciation of an act by the actor and its appreciation by the observer from outside must be related to each other if we are to have a complete understanding. The movement observed from the outside by another is also observed by the actor. This observation is necessary if the actor is to connect it with the ideas that precede the movement. It is probable that the movement has increased meaning for the passive observer because he has made similar movements himself and appreciates them in terms of his own preceding ideas. On the other hand, the observer can become aware of the ideas of the man who moves only in so far as they are reported in words and in this way ideas are translated into movements. The words become part of the behavior of the actor, although these again are of value in understanding the act only as they are interpreted by the listener and observer in terms of his own earlier internal experiences.

The fact that each set of experiences can be translated into the other has led at times to an insistence that each is the only one that exists. Certain philosophers from Berkeley on down have insisted that movements and all of the objects that are moved or that affect in any way the experience of an individual are of value only so far as they become ideas for him and hence that the real objects have no existence. This would make the subjective phase of experience the only one that exists or that needs to be considered. This theory, which has almost ceased to be held today, is known as subjective idealism or solipsism. The complementary position that we can know only the outside of an individual or his acts and have no right to ask about what the ideas and similar processes may be is still held, in fact has developed only in the last score of years, and is known as behaviorism. Each seems to the neutral mind a little one-sided and unjustified. We shall hold to the more naïve assumption that both phases of man's experience, both ways of studying and interpreting his acts are valid and that both must be used if we are to have a complete understanding of the behavior.

In addition to understanding the responses of a man we must also attack the problem of how he knows. The ideas and sensations that seem to precede his act are also of interest in themselves. One should know how they themselves originate as well as know how they modify the movements of the individual. It may be quite as important to solve the problem of how the man sees, how he remembers, and the limits of accuracy of his recall as it is to understand how and why he acts. Our full duty by this side of the problem will not be fulfilled until we appreciate how one comes to original conclusions and the circumstances that are likely to make those conclusions adequate. Without these facts and a satisfactory explanation of them we would not know how the man who observes the behavior of another would be able to perceive that behavior and under what conditions his perceptions would be correct, and how he might interpret them or draw correct conclusions concerning them. The group of phenomena connected with knowing in its various phases constitutes a very real and important problem for psychology.

Still other concrete phenomena of the human individual that we must explain are the emotional or feeling experiences or reactions. The likes and dislikes and more pronounced reactions of hating, fearing, and loving are the most highly colored of our inner life and also profoundly modify our behavior. If we should neglect to consider them and try to interpret human action as a mere response to stimuli or even to stimuli and ideas of different kinds, we would neglect an important series of causes. The emotions, too, have been reduced to movements of different types, mainly of the muscles in the walls of the blood vessels and in different visceral organs and to the secretions of glands especially of the endocrine glands. The effects of these secretions and widespread internal contractions are known both by observation from without and by immediate appreciation of their effects upon the inner experience. The former method is effective only for the more obvious changes of blushing or growing pale. If it goes farther, it must use instruments and indirect methods. The man who is pleased or is angry knows of the bodily changes directly, although he cannot trace them all to their specific organs. He appreciates them as thrills or as revulsions. Even modern science has not discovered all of the changes that take place in a man during an emotion.

Acting, knowing, emotion, or feeling described above together constitute the three most important aspects of human behavior. It should be insisted that they are aspects of a common experience and not separate events or different parts even of a single whole. There is very little response that is of interest to psychology that is not accompanied by awareness of the act. True, there are many reflex and automatic acts which the body performs without the knowledge of the individual. Many of these fall within the province of physiology so far as concerns the reflexes. Most of the automatic acts were once appreciated by the actor and only later ceased to be appreciated as they are performed. On the other hand, most ideas involve acts, and most reception of experiences through the senses is only possible if the sense organs are adjusted to the stimuli. The motor responses also contribute to the actual content of the knowledge processes, and, some authorities insist, are the finally essential elements in making them possible. Similarly, few acts are performed without some change in the feeling or emotional attitude. Then, too, very few of the pure knowledge processes are without some tone of pleasure or pain. All of the aspects of experience are involved in any single event. The older psychologies attempted to classify the mental processes into sensation or knowing, feeling and will. Modern psychology uses these terms only for the sake of convenience in reference. Practically all modern psychologists specifically deny that they are entirely different entities or even different forces or functions.

While it is well to refrain from too hard and fast divisions and even definitions which can hardly be made to avoid the implication that they refer to specific functions, it is still necessary to indicate the meaning of some of the more important terms. Man's acts as seen from the outside are known collectively as responses. Each is supposed to be due to an external stimulus which evokes them. The words applied to the external phase of his activity are self-explanatory. What the actor appreciates during the movements, his awareness of the stimuli and of the considerations which they arouse in him, we know collectively as his consciousness. That covers also his intentions with reference to the movement, his feeling and emotional responses and all else of which he is aware.

More involved are the implications of the word *mind* which is popularly and by many of the older psychologists used in connection with the series of subjective phenomena or the definite entities or forces presumed to make them possible. The term has had so many meanings and so many of these have become out of date through advances in knowledge and changes in fundamental assumptions and theories that the term is no longer used except as a vague descriptive way of referring to all of the phenomena, subjective and objective, that are involved in behavior and the knowledge that goes with it. Thus the term *mind* will be used only as a general term to indicate one phase of the subject matter of psychology. The adjective *mental* is more convenient and will be used to designate the more subjective phases of behavior and the explanations that go with the series of conscious events that many theories assume.

For our present purpose we may say that what an onlooker sees of a man when he acts constitutes his behavior. Behavior also includes responses which are not directly open to observation, but may be recorded by suitable instruments. These include changes in respiration, circulation, and various internal responses. Opposed to these are the different forms of awareness or knowledge of the individual himself. This taken as a unit we call his consciousness. The two phases may be regarded as mutually supplementing each other.

An important aid to an understanding of how these two phases of man's active and knowing life are connected is provided by a study of the physical mechanism, especially of the nervous system. It is this that makes possible the movements. Incidentally and by inference study of its action and of the disturbances that are produced in it by accident, gives some indication of the physical side of mental operations. This is traditionally the peculiar province of anatomy and physiology, but the problems of psychology are so closely related to these structural and functional aspects of man's organism that we cannot ignore them. For that reason we shall begin with a summary of the structure and action of the nervous system. It is very difficult to determine exactly where the task of psychology ends and that of anatomy and especially of physiology begins. We shall not attempt it, but shall use all the knowledge we can bring together to bear upon each of our problems. We shall use that knowledge to solve our own problem of why the living human acts as he does and thinks as he does. We shall not discuss the structure and function of the organism for itself.

This dependence of psychology upon the biological sciences is but one aspect of the general interconnection among the sciences. Chemistry depends upon knowledge that has been brought together by the physicist, and physics in turn upon chemistry to so great a degree that it is now difficult to say when a specific problem is physical and when chemical. Biology is in many of its phases very closely dependent upon chemistry. From one standpoint much of physiology is really a highly complicated organic chemistry. And physics too is essential to the solution of many problems, both in physiology and in more general biology. Psychology stands to physiology in somewhat the same relation that physiology stands to chemistry and physics. It must take advantage of what they contribute and apply it to its own problems.

At the same time psychology has relations to philosophy in many of its problems, and must also use the materials offered by anthropology. It stands in a definite give-and-take relation with economics where its problems bear upon labor and similar industrial questions. Even more close is the connection with sociology, for man is nearly always a social being. Sociology must use the material collected by psychology on the nature of the individual man, and psychology goes to sociology for a knowledge of the way man in the mass differs from the isolated individual. In short if psychology is to give a full account of man's behavior or knowledge, it must use the material provided by all of the biological sciences, and by physics, and more rarely by chemistry among the physical sciences. There can really be no absolute line of demarcation between the sciences. The divisions made are for convenience only. They can be established sufficiently to give a man who follows one science an idea where he should begin his work, but cannot be regarded as marking boundaries that determine beyond question where he should stop.

Psychology then is a science of man as active rather than as passive. It is the science of man as a conscious or knowing being rather than as a mere mechanically reacting mass. On the outward side it is a study of man as a self-directed organism in the sense that his movements are determined from within his own organism rather than by mere external forces. Our aim is, however, to determine the internal conditions of his acts and refer them to their antecedent causes within and without. One characteristic of the phenomena that falls particularly within the range of psychology is that the acts of one time are determined by events of the more or less distant past. In the animal series psychology may be said to begin where learning begins. In its simplest form learning may be defined as the modification of action by events that have occurred a longer or shorter time before the movement takes place. With a few doubtful exceptions this marks off the animal from the vegetable, and roughly we can measure the development of mental action by the degree to which an act is an outgrowth of remote rather than of immediate factors. In the solution of the problems that arise we shall make use of all pertinent knowledge, with little reference to the science that may have developed it.

THE METHODS OF PSYCHOLOGY

Psychology has been divided into fields in part by the methods that have been used in studying the common subject matter, in part by the material that is studied, in part by the presuppositions which the man who is studying had in advance. The methods are usually classed first into the observational and introspective. In the observational, one must study another man or animal. He may merely keep a record of the movements of the individual in response to stimuli or that are made spontaneously, and see how they may be related to the stimuli that preceded and may be presumed to have caused them. This was the method used by some of the early writers. Unless the conditions are kept constant for observer and observed and the results are recorded at once for each movement, the conclusions are likely to be inaccurate. When properly controlled, observation develops into the experimental method.

Introspection. — What was long regarded as the peculiar method of psychology is internal observation or introspection. This is observation by the man who thinks or acts, of the changes that go on within him during various mental and physical processes. At first introspection was largely incidental. A man became interested in what went on during some bit of recall or perceiving. He may have noted down a description at the time or he may have merely remembered it for later recording. For a century or more the older men disputed whether introspection could be accurate. Comte and others argued that one could not observe a mental fact without by the very fact changing it. One could not simultaneously perform a task and observe the act. Tetens had answered this formal object a half century before Comte. Tetens pointed out that any mental process persisted in consciousness as a memory after-image which much resembled a photograph of the actual process. If one studied the memory after-image one had a perfect record of what had gone on and the process itself was not affected. Careful observation shows that many readings of scales and other observations of the physical sciences are also held in these memory after-images until they can be recorded. One cannot look both at the scale and at the paper on which one writes. In this respect observation and introspection are on the same level.

Experiment. — Observation and introspection are in modern investigations used only under the controlled conditions of an experiment. The psychologist does not trust to casual introspection, but places the observer in an instrument that will permit registering the various stimuli that act upon him and the time of their occurrence. It may record also the movements which the observer makes in response to the stimuli, so that they may be measured or otherwise studied at leisure. Frequently the experiment consists in solving some problem or performing some task. The time required can be measured, the degree of success can be recorded, and all of the stimuli or incentives to the execution of the task carefully determined. With the exception of a few cases, introspection is incidental to the experimental investigation of the task. The individual may well be questioned as to the conscious antecedents of his acts, or he may be encouraged to make spontaneous observation of mental states that seem to him to be important. These must also be carefully recorded as soon as reported if they are to have more than incidental value. Both observation and introspection have become mere tools in connection with experiments.

Statistical Methods. — Many problems in psychology involve the study of groups of individuals rather than single persons. All results obtained by observation or introspection need to be confirmed on a number of men before they can be accepted. Men differ slightly or much in any capacity. To be given application to man in general these varying results must be combined in a single statement or law. It is necessary to know both the central point from which they diverge, and the degree of divergence. This holds both for different measurements on the same individual and for the measurement of different individuals. For the attainment of this end various mathematical procedures have been developed. Their use constitutes a very important auxiliary to any method and in some cases becomes almost an end in itself.

Testing Human Capacities. — These statistical methods are of special application when the psychologist desires to know more of the general abilities of individuals. Testing intelligence has become one of the most important functions of applied psychology since intelligence determines what an individual can accomplish in school, in business, or even in the more mechanical occupations. Tests of a long list of other abilities have been developed, but intelligence is more accurately measured and has interested more workers. Each of these forms of ability has its own test and each of the tests requires its own technique. However, all are dependent for their interpretation upon statistical procedures. Each of these tests has raised many theoretical questions as to how much the ability tested depends upon heredity, and how much upon training or environment, as to how close the relation may be between the different capacities, and many others. These questions of interrelations have required for their solution the use of coefficients of correlation, a tool that has become of the widest application in psychology.

THE FORMS OF PSYCHOLOGY

The Divisions of Psychology. — Classifications of psychology have been made upon the basis of the methods used in the investigation, upon the other sciences with which the founder of the special school would connect psychology, and upon the material that is treated. Most recent schools, as the behavioristic, the Gestalt, and the 'understanding' psychology have been given their names from the general theory of metaphysics that the author of the book or the founder of the school held. One of the older divisions was into the rational and empirical psychology. The rational method has ceased to be used extensively since psychology became a science. Brentano distinguished an empirical psychology from an experimental one, although now the two would coalesce. Most empirical results are obtained through experiment.

Physiological Psychology and Psychophysics. — Two branches that were historically widely recognized are physiological psychology and psychophysics. Both forms received their names from the titles of important works on the subject. Wundt, up to that time a physiologist, wrote a comprehensive volume that included much that was known of the psychology of his day and called it *Physiological Psychology*. Fechner, a physicist, a score of years earlier had written a volume in which he discussed primarily the relation between the physical stimulus and the conscious state, which he called Psychophysics. Both may be said to have been incorporated in the general science and so to have lost their earlier importance. Practically all psychologists now include a discussion of the physiology of nerve and sense organ in connection with each topic. Psychophysics is also treated by each writer in his own way.

The Different Fields of Psychology. — More important for current usage is the classification of psychologies on the basis of the subject matter treated. Most psychology deals with the adult human individual, but recently many additional and special fields have been developed.

Social Psychology. — Society, or man in the mass, may be studied, as well as the individual. A society shows many characteristics different from and in addition to the qualities of the individual. A mob, for example, will do many things that few if any of the individuals who compose the mob would countenance in calm moments. These and other phases of group psychology have been studied, and a series of important laws developed. Race psychology deals with the broader mental differences between races and is a natural extension of social psychology but has been less fully developed.

Genetic Psychology. — A second group of divisions of psychology, genetic psychology, treats the less developed types, either with the object of throwing light upon more complex human behavior or for their own sake. The most fully developed of these is *animal psychology.* The laws of animal action and their limitations as compared with man have always interested students, but until within the last three decades most of the conclusions were based upon anecdotes or, at most, upon the chance observations of travelers and naturalists. These were obviously not trustworthy. More recently, experiments upon animals have been carried on by both biologists and psychologists, with very important results. The behavior of typical animals from the protozoa to the apes has been studied exhaustively. Much light has been thrown upon their own activities, and many points in human psychology have also been illuminated by these results. The development of the individual has also been investigated. *Child study* has offered a number of conclusions that make easier an understanding of the complicated activities of man. The earliest years and the period of adolescence have received most attention.

Abnormal Psychology. — Still another important series of problems has arisen in connection with different forms of mental deterioration, the psychology of the abnormal, or pathological psychology. The relation of these studies to normal psychology has been twofold. They have greatly aided in an understanding of the normal individual. One is very much more certain that a voluntary act depends upon certain stimuli or sensations when it can be shown that the absence of that stimulus causes a defect in the movement. Disturbances of the self have given a more profound knowledge of what the self is or is not than centuries of speculation and introspection. Slighter defects of sensation, color blindness, and partial deafness, not to mention the impairment of memory and related processes, have all given valuable aid in the unraveling of psychological problems, or have substantiated results obtained in other ways. On the other hand, psychological methods and psychological results have been adapted to the study of the abnormal and defective minds with much theoretical and practical benefit. Certain standardized tests have come into use which make it possible to determine within fairly close limits the degree of intelligence of the individual. These have proved of value in the schools in selecting the children who are unable to profit from the usual training, and make it possible to give them special instruction. It has been shown by an examination of criminals and paupers that, in a large number of cases, a mental defect is responsible for their failure to fit into society; and the necessity for special care that shall provide the ounce of prevention has been emphasized. Many of the methods used today for the diagnosis of insanity have also been developed in psychological laboratories, and much of the treatment has been an outgrowth of psychological principles or an application of psychological methods.

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CHAPTER II

THE NERVOUS SYSTEM

The physiological determination of human behavior is to be found in the action of the nervous system. The nervous system is to be looked upon primarily as the means by which stimuli that are derived from changes in the physical environment are enabled to produce contractions in muscles and so to adjust the man to those changes. The nervous system is made up of the brain and spinal cord, with the sense organs and the nerves which connect them with the brain, together with the motor nerves that extend from the brain to the muscles. The brain fills the upper part of the skull, the cord the upper two thirds of the spinal column. The sense organs are scattered over the outer surface and through many of the tissues of the body. Like all other tissues of the body, the nervous system is made up of cells. The unit of the nervous system is the neurone, and the fundamentals of the action of the nervous system can be understood if we appreciate the way these neurones act.

Behavior of Lower Organisms

Cells and Their Life Processes. — It is much easier to comprehend the action of higher animals and of their parts, if we see how they are related to the structures and functions of the simplest animals from which we believe they have evolved. The separate elements of the human structures are assumed to have retained the properties and functions of the one-celled protozoa. The principles that have been developed by a study of the lowest may be transferred to the higher. The amœba is used as a type of the single-celled animal. Like all living cells it is a minute drop of liquid of highly complex chemical composition, as yet only partly known, that is contained and given form by a delicate semipermeable membrane. Since the fluid is the substance from which all other living matter develops, it is known as protoplasm (the first flesh). We know that protoplasm is made up of highly unstable chemical compounds, mostly hydrocarbons, but the different components have never been completely isolated or analyzed. Whatever the composition of this chemical substance, it is constantly undergoing change. It takes to itself other organic compounds and oxygen and gives off carbonic acid. It is constantly receiving something from the medium in which it lives and giving off waste products. Both of these changes take place through the semipermeable membrane by a process which the physicist calls osmosis. Within the body of the cell is a darker spot, known as the nucleus. This nucleus is closely connected with the nutritive processes and the subdivision of the cell. Much still remains to be known of the life processes in the cell. We can give only the briefest account of what is known — that some chemical processes must go on within the cell, that the materials involved are admitted to the cell by osmosis through the membrane, and that these processes taken together make possible, if they do not constitute, what we call life.

The Activities of Protozoa. — If we study the activities of the amœba, we find that in a simple way it can do almost everything that the most highly organized animal can, and that it follows the same fundamental laws of behavior. It takes nourishment, it breathes, and, what is most important from our point of view, it moves upon stimulation of any part. If particles of a certain chemical composition come into contact with its membrane, it enfolds them, and the process of digestion through the membrane of the cell begins. If particles of another kind touch it, it moves quickly away. When near a solid body, it may send out a prolongation of its body in the form of a foot or what is known as a pseudopod (false foot) which attaches itself to the surface, and the whole body then draws itself up to the foot, which is then withdrawn into the rest of the body. The single cell is stomach, lung, and organ of locomotion, in one.

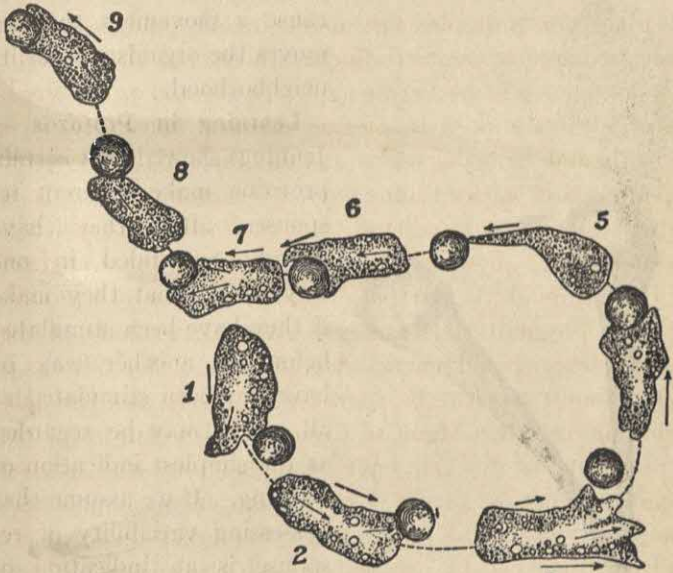

FIG. 1. — Amœba chasing and attempting to ingest a euglena. (From Jennings.)

Responses of Protozoa. — Study of the responses of the amœba and of the stimuli to which it responds shows its similarity to the higher organisms. When stimulated gently by a solid object, its activity is not changed, but if the excitation is stronger, it at once stops all movement and rolls up into a ball. If the stimulation is continued, it may send out a pseudopod on the opposite side and roll away from the stimulus. In these two ways the protozoa respond to light, heat, the motion of the liquid medium, the attraction of gravitation, and to the presence of chemicals in the liquid. In general, beneficial stimuli have no effect, while harmful stimuli cause a movement that removes the organism from its neighborhood.

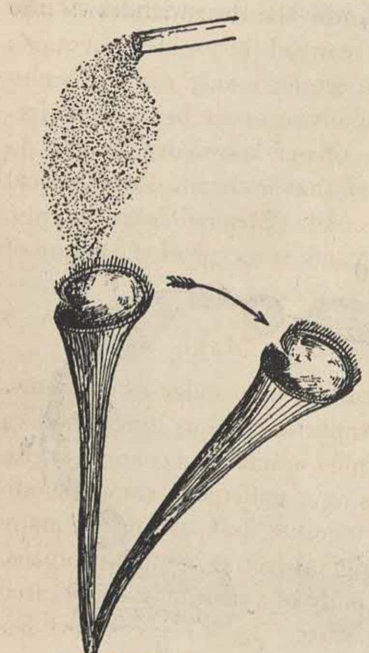

FIG. 2. — Stentor stimulated by carmine particles. (From Jennings.)

Learning in Protozoa. — Jennings showed that certain protozoa make different responses after they have already responded in one way, from what they make if they have been stimulated before in another way or have not been stimulated at all. This may be regarded as the simplest indication of learning. If we assume that possessing variability of response is an indication of intelligence, these animals may be said to give evidence of the most rudimentary intelligence. Thus the stentor, the protozoön in Figure 2, when stimulated for the first time will withdraw into its tube. After several stimuli, each of which has produced this withdrawing, the stentor changes its form of response to bending to one side to escape the contact. Later it may, when strongly and repeatedly stimulated, as by permitting water mixed with carmine particles to reach its disk, loosen its hold on the tube and swim away.

Each of these responses is to be thought of as the result of the transfer of a chemical stimulus from the point of stimulation to a more or less remote portion of the cell where the movement is made. Did we know the exact nature of the processes in these simplest cells, many of the problems of man's action would be solved. So far we have only made a beginning in that direction, although advances are being made frequently. At the present stage of our knowledge we can do no more than express the belief that a chemical or physical explanation may some day be found. Meanwhile we may use the action of these simple organisms as a type of the action of cells in general.

THE NERVE CELLS IN MAN

Man a Colony of Cells. — That the unicellular animal shows these different responses is important to us since modern theory thinks of man or any higher animal as a colony of cells. The cells in the higher animals have undergone various modifications as a result of living together, but still retain many of the characteristics of the original free-swimming protozoa. For our present purposes, the body of a man may be pictured as a mass of cells of different sorts. Each class or sort has developed specialized capacities which fit it to fulfill some one function. With increased capacity for this function, others of the primitive capabilities have been lost. Nevertheless the rudiments of all the capacities of the complex organisms are to be found in the unicellular beings. In the body, the nerve cells are among the least modified. Unlike the bone cells, for example, that become so filled with salts as to retain but slight similarity to the original, the nerve cells lack motion alone of the capacities of the prototype. In the early stages of development the nerve cells do also move. Dr. Speidel has shown recently that, as the processes grow, they move about as if seeking a suitable location. Only certain of the blood corpuscles retain more of the original properties; the leucocytes, or white blood corpuscles, seem to live almost as independent an existence in the blood stream as the amœba in its watery medium.

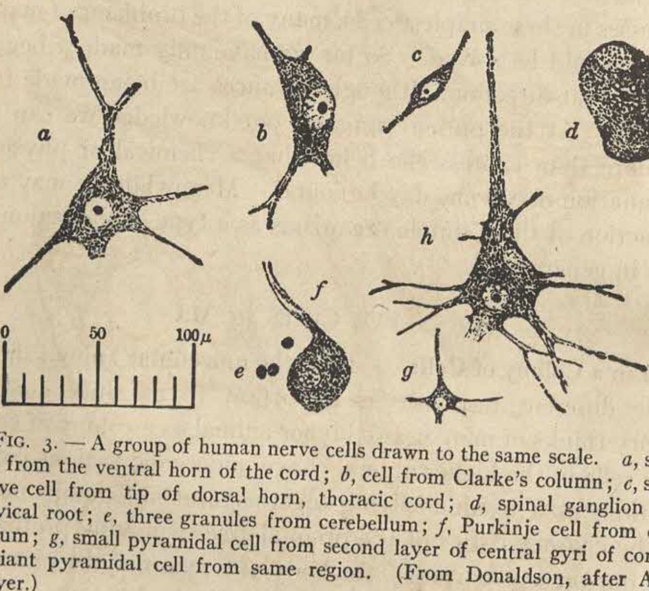

FIG. 3. — A group of human nerve cells drawn to the same scale. *a*, small cell from the ventral horn of the cord; *b*, cell from Clarke's column; *c*, small nerve cell from tip of dorsal horn, thoracic cord; *d*, spinal ganglion cell, cervical root; *e*, three granules from cerebellum; *f*, Purkinje cell from cerebellum; *g*, small pyramidal cell from second layer of central gyri of cortex; *h*, giant pyramidal cell from same region. (From Donaldson, after Adolf Meyer.)

Morphology of Neurones. — The cells of the nervous system have retained especially the sensitivity and conductivity of the unicellular forms. In brief, the elements of the nervous system, known as neurones (also spelled neurons), consist of a central cell, the representative of the cell body, and numerous processes that extend in all directions from that cell body. The cell body is of a more or less irregular shape and varies in diameter from about $\frac{1}{200}$ to $\frac{1}{10}$ of a millimeter. The outlines can be determined from Figures 3 and 4. Within the body of the cell are found a nucleus and a nucleolus, as in all cells.

Within the protoplasm are small particles that stain easily, named Nissl or tigroid bodies, the former after their discoverer. In many cells can also be seen fine fibrils that run through the bodies of the cells and into the processes. It is not possible, however, to assert positively what function these different parts of the cell have. The nucleus and Nissl bodies are probably closely connected with the nutrition of the cell.

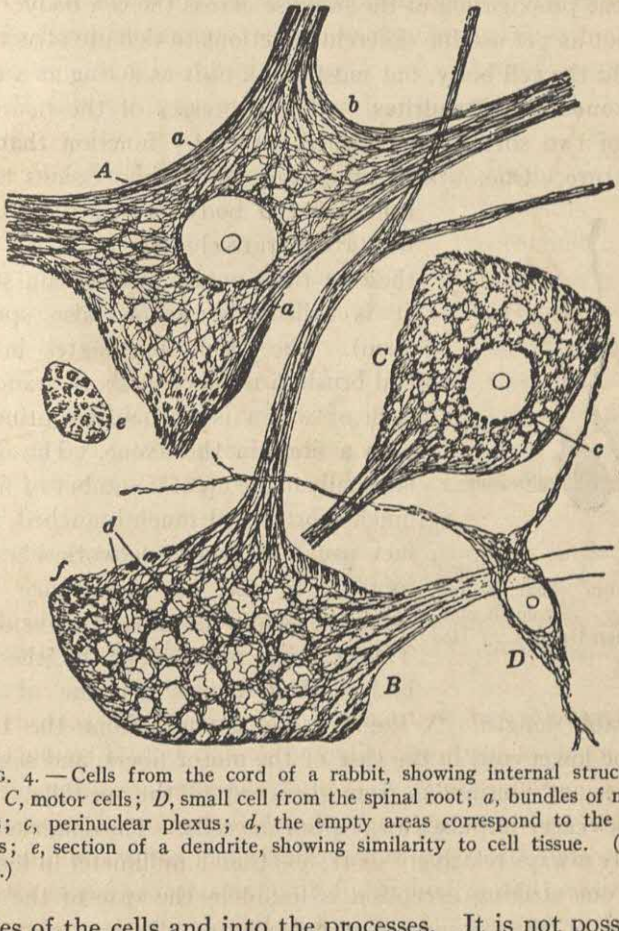

FIG. 4. — Cells from the cord of a rabbit, showing internal structures. *A*, *B*, *C*, motor cells; *D*, small cell from the spinal root; *a*, bundles of neurofibrils; *c*, perinuclear plexus; *d*, the empty areas correspond to the Nissl bodies; *e*, section of a dendrite, showing similarity to cell tissue. (From Cajal.)

Some theories assign the function of transmitting the nerve impulse through the cell to the fibrils, but the balance of opinion is opposed to assigning to any special structure in the cell the propagation of the impulse across the cell body. We cannot as yet ascribe different functions to definite structures within the cell body, but must think of it as acting as a unit.

Axones and Dendrites. — The processes of the neurones are of two sorts, distinguished rather by function than by structure. One, which serves to conduct impressions away from the cell body, is relatively long, with comparatively few branches, and these at right angles to the main stem. It is called the axone (also spelled axon). The axone terminates in the end brush, a number of short branches, each of which is probably continuous with a fibril in the axone. The other is usually made up of a number of fibers much shorter and much branched, is in fact usually a thick network like the roots of a tree, an appearance that gives the whole its name, the dendrite. This carries impressions to the cell body. The axones may be of considerable length. A single axone extends from the brain to the lower cord in the case of the motor fibers, and sensory axones are continuous from the cord to the medulla. The axones carry impulses away from the cells. The dendrites are nearly always relatively short, less than a millimeter in length. The one striking exception is found in the case of the dendrites of the sensory neurones whose cells are located in the spinal ganglia, masses of nerve tissue near the cord. These carry impressions from the organs of the skin and lower body to the cord and brain. The process that runs to the skin may

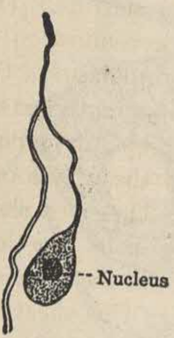

FIG. 5. — 'T'-shaped cell from spinal ganglion of frog. (From Boehm-Davidoff-Huber's "Histology.")

be two feet or more in length, extending from the skin of the toe, for example, to the T-shaped cell body in a spinal ganglion in the lower part of the back. In appearance it is not to be distinguished from the fiber of an axone, but its function is to carry an impulse to the cell, the function of a dendrite. It is sometimes called a teledendrion, or long dendrite, to avoid the difficulty of classing it either with the axone or with the dendrite.

The Sheaths of the Axones. — The axones are composed of a central core and of one or two coverings or sheaths. The central core is of primary importance for the conduction of nerve impulses. It is continuous with the protoplasm of the cell body. It is made up of fibrils that are apparently extensions of the fibrils of the cell body, surrounded by a more fluid protoplasm. Directly about this in most of the nerves is a fat-like covering, the medullary sheath. The medullary sheath is not merely protective or insulating in its function, but is assumed to share with the central core in the chemical activities that constitute the nerve impulse. This sheath is lacking near the point where the axone connects with the cell body and on the end brush. Peripheral nerves, those outside of the brain and cord, have a second sheath outside of the medullary sheath, the neurilemma, or Sheath of Schwann. This sheath shows notches or nodes at short intervals. Each of the nodes between the notches has a nucleus of its own which shows that it is a unit apart from the axone. The neurilemma is essential to the growth of the axone. It can be shown to be effective in making possible the regeneration of an injured nerve, in certain cases. When an axone is cut off from the cell body, the portion beyond the cut dies. The neurilemma cells do not die, however, and aid in the growth of the core of the axone from the central stump. The arrangement of core and sheath are shown in Figure 6.

We regard the central core as the path of what we call the nerve impulse, although the medullary sheath probably aids in the transmission of the impulse. In an ordinary nerve in the periphery of the body several thousand of these axones may be grouped together. In the optic nerve, *e.g.*, it is estimated there are as many as 100,000. In addition to the truly nervous cells, the neurones, there are everywhere in the nervous system a large number of non-nervous cells, the neuroglia cells. They are supposed to have no part in the conducting function, but to be largely supporting structures. A typical form of neuroglia cell is shown in Figure 7.

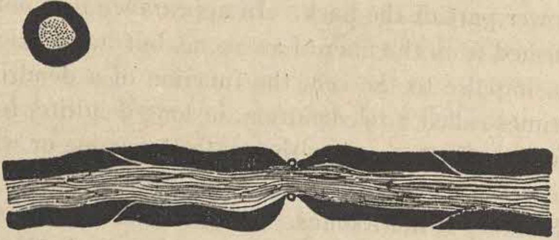

FIG. 6. — Longitudinal and transverse sections of a medullated nerve fiber. The myelin sheath is shown in black; the central protoplasm shows its fibrous structure. (From Barker, after Biedermann.)

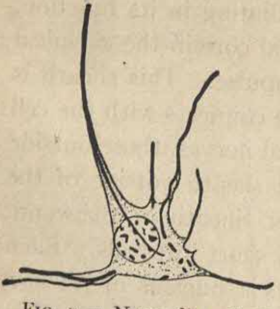

FIG. 7. — Neuroglia cell. In this preparation the cell is prominent. In the more usual method of staining, the fibers are more striking and give the so-called spider cells. (From Huber, after Joseph.)

The General Plan of the Nervous System

The General Outlines of the Nervous System. — The nervous system of man is altogether made up of these neurones held together by their own cohesion and the pressure of the bones and other surrounding tissues. The peculiarities of appearance of the different structures are due to the way in which the different elements are combined to constitute the masses. As one looks at the nervous

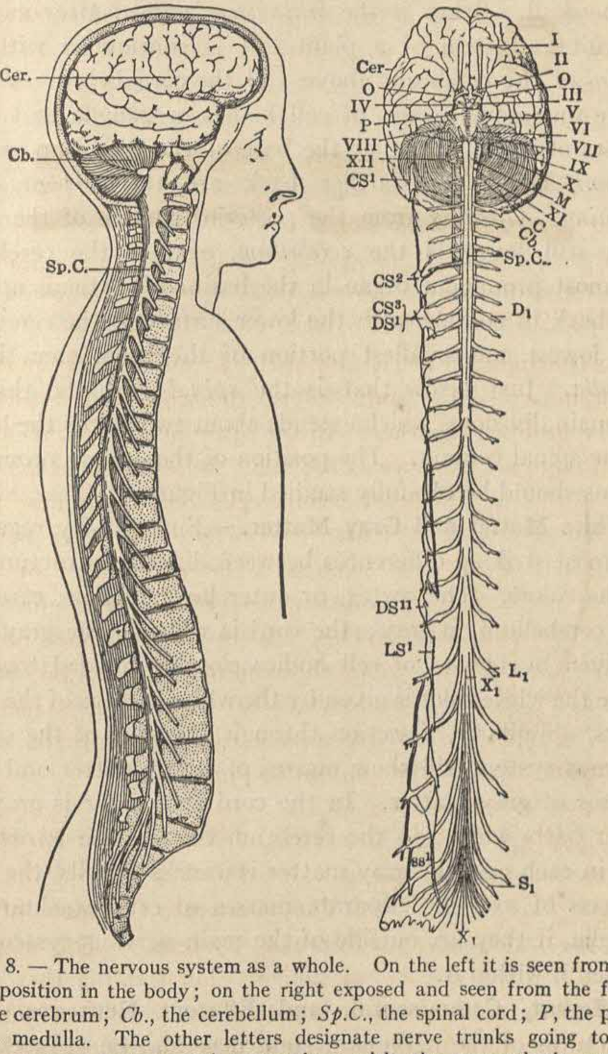

FIG. 8. — The nervous system as a whole. On the left it is seen from the side in position in the body; on the right exposed and seen from the front. *Cer.*, the cerebrum; *Cb.*, the cerebellum; *Sp.C.*, the spinal cord; *P*, the pons; *M*, the medulla. The other letters designate nerve trunks going to the central nervous system and connections with the sympathetic system. (After Bougery.)

system of a mammal, one may distinguish three parts. The largest is the *cerebrum*, which fills the upper portion of the skull. Below is the *brain stem*, named after analogy of fruit and stem of a plant. It is continuous with the tissues of the cerebrum above and the cord below. Within it are numerous masses of cell bodies or ganglia and other masses of fibers. Just at the base of the cerebrum are the *thalami*, below and farther back are the *corpora quadrigemina*. Growing from the posterior surface of the brain stem still lower is the *cerebellum*, next to the cerebrum, the most prominent organ in the brain. It extends upward and back in contact with the lower surface of the cerebrum. The lowest and smallest portion of the brain stem is the *medulla*. Just below that is the *spinal cord*, the third of our main divisions, which extends about two thirds the length of the spinal column. The position of these more prominent organs should be carefully studied in Figure 8.

White Matter and Gray Matter. — Superficially regarded, the most striking differences between different structures are in the colors. The cortex, or outer layer of both cerebrum and cerebellum, is gray; the cord is white. The gray color is given by masses of cell bodies closely crowded together, while the white color is given by the white sheaths of the nerve fibers. Similarly, a section through any part of the central nervous system will show masses of white matter and other masses of gray matter. In the cord the center is gray, the outer parts white; in the cerebrum the relation is reversed, but in each case the gray matter is a mass of cells, the white a mass of axones. Separate masses of cells are known as ganglia, if they are outside of the main nervous system, and nuclei, if within it.

Afferent, Commissural, and Efferent Neurones. — The structures of the nervous system may also be grouped with reference to function. From this standpoint cells and fibers may be divided into sensory or afferent, associative or commissural, and motor or efferent. The sensory neurones are connected with sense organs, directly or indirectly. The axones conduct from the periphery to the center. The first cells of sensory ganglia are outside of the central nervous system, either in the sense organ or in ganglia near the central nervous system, and their axones connect with other cells nearer the brain. The commissural cells and fibers transfer the impression from sensory cells to motor cells. The motor or efferent neurones stand in immediate connection with the muscles, or with neurones which serve to innervate the muscles, — are members of the chain that conducts impulses from the centers outward. The neurones that possess these different functions cannot be distinguished structurally. The functions depend rather upon the connections in which the neurones are found than upon their structures.

Development of Embryo. — To understand the structural relations, one must go back to the development of the nervous system as a whole. Many relations, very complicated in the developed organism, are very simple in the earlier stages. The complexities are caused by the conditions of growth. Our sketch of the development must be very brief, with many omissions, but even this may be helpful at some points. The complete adult is developed from an original cell, the fertilized ovum, by a process of division. The original cell divides into two, each of these into two, and so on. At first the derived cells are exactly like the original so far as can be made out. They are grouped compactly. The first sign of differentiation comes when the mass of cells divides into two layers, an outer, the ectoderm, and an inner, the entoderm. Soon a third intermediate layer develops from the others to constitute the mesoderm. These layers may be distinguished throughout the remaining development and give rise to different parts of the organism. From the entoderm develop the inner wall of the internal organs, and certain organs, as the liver and pancreas. From the mesoderm develop the supporting structures, connective tissue, bone, muscle, and the body of most of the internal organs. The ectoderm develops into the skin and its appendages, the mucous membrane of the mouth and nose, and, what concerns us most, into the nervous system and the nervous parts of the sense organs.

The Development of the Nervous System. — It is interesting to note that the outer layer of the embryo gives rise to the nervous system which finally becomes embedded so deeply in the structure of the body. Very early in the em-

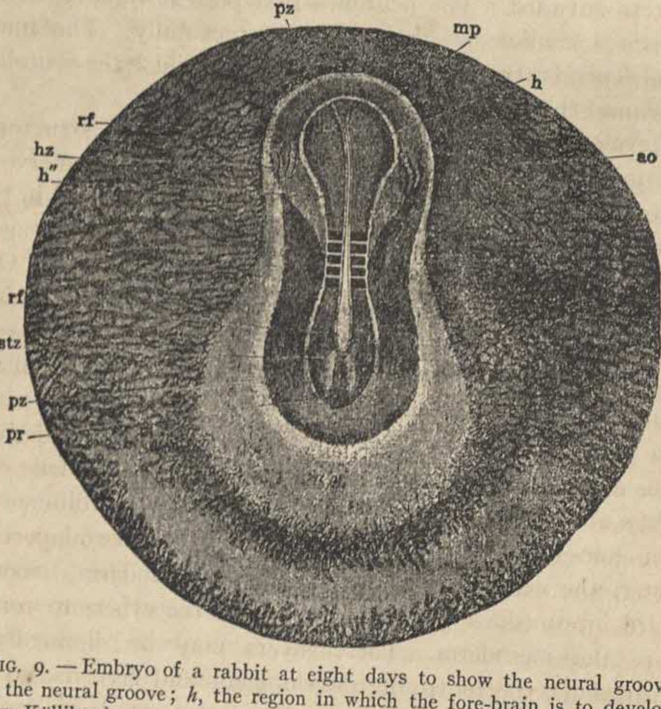

FIG. 9. — Embryo of a rabbit at eight days to show the neural groove. *rf* is the neural groove; *h*, the region in which the fore-brain is to develop. (From Kölliker.)

bryonic life, within the first few days, there appears upon the surface of the embryo a slight depression known as the neural groove (Fig. 9). This gradually grows deeper, and finally the upper edges grow together and form the neural tube (Fig. 10). From the walls of this tube the entire nervous system grows. The upper end becomes the brain, the other longer portion, the spinal cord. The cells that line the tube first give off masses of cells with radiating fibers which serve as a supporting structure or scaffold (Fig. 11). Some at least of these develop later into neuroglia cells, the supporting tissue of the central nervous system. This first supporting structure takes the general form of the part that is to develop and may be said to prepare the way for the truly nervous portions. After the supporting or ependymal structure is well developed, later divisions of the cells lining the tube give rise to embryo neurones or neuroblasts. These make their way outward toward the position they are to occupy in the adult cord. As the neuroblasts develop they send out processes, axones and

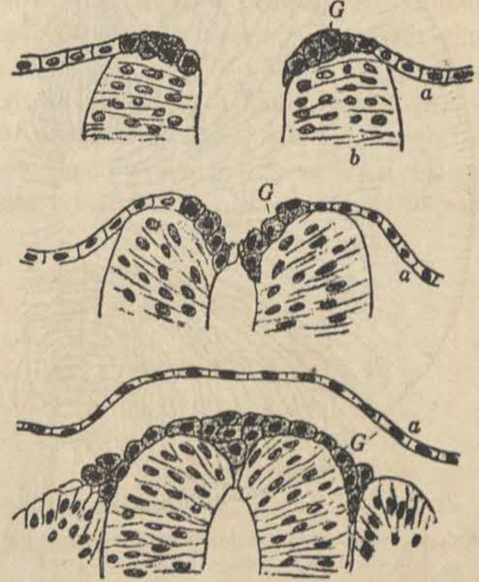

FIG. 10. — Closing of the neural groove. The figure at the top shows the groove still open; in the next, the sides approximate each other; in the lowest, the closure is complete. *G*, the cells from which the spinal ganglia develop; *a*, the ectoderm; *b*, the epithelial lining of the medullary tube.

dendrites. The axones grow outward to the structures they are to supply. These constitute the rudimentary white matter of the outer layer of the cord. A section of the cord at the end of the first month shows the layer of epithelial cells about the neural tubes from which all have developed. Outside of these are the neuroblasts, and in the outermost layer are the axones that have grown from the neuroblasts to constitute the white matter (Fig. 13).

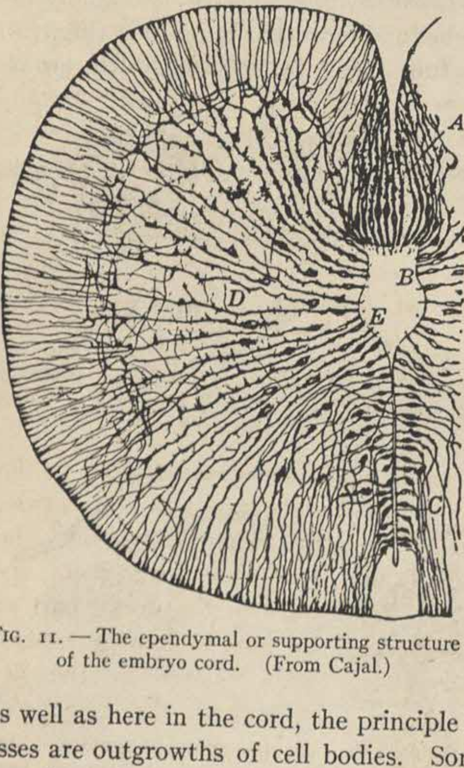

FIG. 11. — The ependymal or supporting structure of the embryo cord. (From Cajal.)

The Growth of the Axones. — Everywhere in the brain, as well as here in the cord, the principle holds that the processes are outgrowths of cell bodies. Some of the fibers that constitute the white matter in the cord are axones developed from cell bodies in the brain stem. Others are outgrowths of neuroblasts farther down in the cord. The axones grow from the cord to developing tissues all over the body. On the ventral or anterior side of the cord, the neuroblasts send out axones to the muscles. These are to induce the contractions of the muscles when they develop. The development of the sensory axones is a little more complicated. The sensory neurones of the cord are in the spinal ganglia, masses of cell bodies outside of but near the cord. In the adult they are found within the vertebral column. The spinal ganglia develop from small masses of neuroblasts which detach themselves from the neural tube just before the neural groove closes to form the neural tube. Portions of the original ectoderm thus cut off (see Fig. 10, *G*) move away from the median plane, and are surrounded by mesoderm tissue. The original ectoderm cells give rise to neurones. At first the processes of the neurones grow out from either end; one goes outward to the end organ in skin or muscle, the other grows into the cord and sends fibers upward in the dorsal part of the cord or into the central gray. Later in the development, the two processes grow together for a short distance from the cell and then grow off at right angles to the original stem. They thus resemble a 'T,' and the cells are known as the 'T'-shaped cells (Fig. 14, *E*). Before birth the germinal layer stops giving rise to new cells

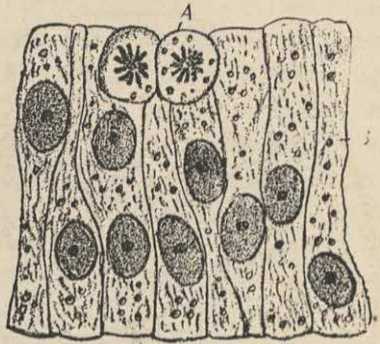

FIG. 12. — Epithelial cells lining the neural tube and germinal cells, *A*, that have developed from them. (From Cajal, after His.)

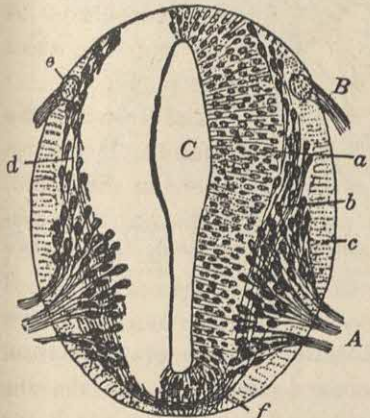

FIG. 13. — Schematic section of embryo cord. *A*, anterior or motor root; *B*, posterior root; *C*, central canal; *a*, epithelial wall; *b*, neuroblasts or embryo neurons; *c*, the primordial white matter. (Cajal, after His.)

and forms a single layer of cells lining the central tube.

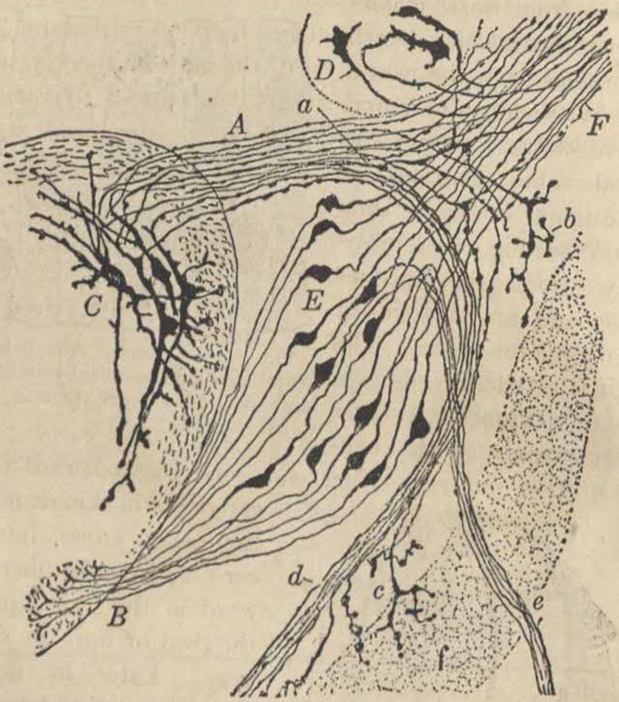

FIG. 14. — Development of dorsal root ganglion with cord. *A*, motor nerve; *B*, posterior root, fibers from ganglion entering cord; *E*, 'T'-shaped cells of dorsal ganglion in their bipolar stage; *e*, sensory nerve, dendrites of 'T'-shaped cells. (From Cajal.)

The Development of the Anterior Portion of the Neural Tube. — The growth of the forward end of the neural tube, the part from which the brain develops, follows much the same plan. The supporting structure and the neuroblasts appear as in the cord. One difference should be emphasized, however, that the neuroblasts are projected farther from the tube and the axones grow inward and extend up or down within the masses of cells. In consequence the white matter is, for the most part, within; the gray, on the surface.

A study of the development of the brain also gives a key to the arrangement of the structures in the adult brain. The first change in the forward end of the neural tube appears at the end of the second week when the front or cephalic end bends sharply. Before this there have appeared constrictions in two places which divide the tube into three swellings or vesicles, known as the *fore-brain*, the *mid-brain*, and the *hind-brain*. A little later the fore-brain and the hind-brain each is divided into two more vesicles. The *tween-brain* is formed from the lower part of the fore-brain, and the *after-brain* from the lower part of the hind-brain. These five first divisions or vesicles give the names to the corresponding parts of the adult nervous system. The cerebrum develops from the fore-brain; the thalamus and other parts from the tween-brain;

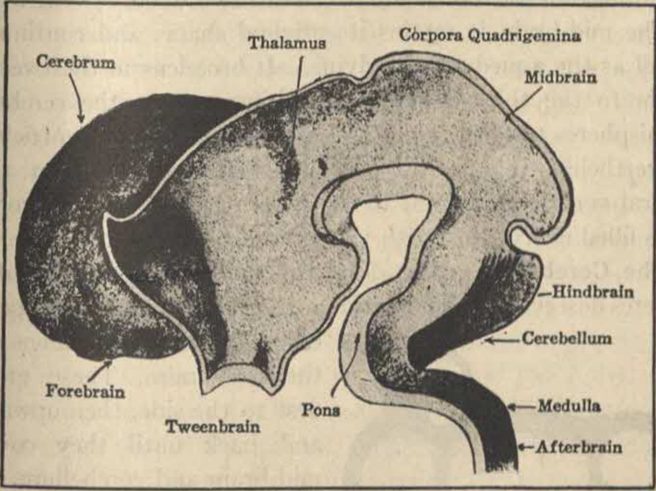

FIG. 15. — The five-vesicle stage of the human brain, giving names of vesicles: fore-brain, tween-brain, etc., and the parts of the adult brain that develop from each. (After His.)

the corpora quadrigemina and other structures from the mid-brain; the cerebellum and pons from the hind-brain; and the medulla from the after-brain. In each the walls are very much thickened and at many points there are very large outgrowths, but all grow from the lining of the original tube by the process of cell division indicated above. The original cavity undergoes changes of shape in many places. It becomes much heightened in the hind-brain to constitute the fourth ventricle; in the mid-brain it retains its original shape, and continues small as the aqueduct of Sylvius. It broadens in the tween-brain to the third ventricle and bifurcates in the cerebral hemispheres to form the lateral or first and second ventricles. Nevertheless it remains continuous throughout from the lateral ventricles in front to the lower end of the spinal cord. It is filled everywhere with the cerebrospinal fluid.

The Cerebrum. — The development of the cerebral hemispheres deserves special mention. (See Fig. 16.) They appear early as lateral swellings on the fore-brain. These grow first to the side, then upward and back until they cover mid-brain and cerebellum, an outgrowth of the original hind-brain. The two hemispheres are distinct from the beginning. They merely come into contact along the median fissure; there is no organic connection between them except at the base. In this growth backward, the cerebral hemispheres are folded here and there, and these folds account for some of the permanent markings upon its surface. Most striking of these is the fissure of Sylvius. This can be seen from the second month. It develops in very much the

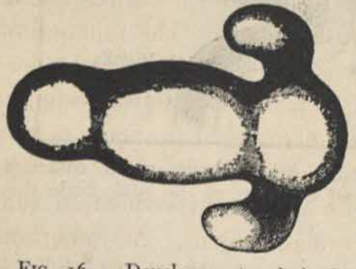

FIG. 16. — Development of brain vesicles seen from above. The hemispheres may be seen growing from sides of fore-brain. (From His.)

same way as the median fissure from the growing together of two outgrowths of the cerebral hemispheres. When these meet, they leave considerable portions of their superficial areas in juxtaposition well below the surface. The walls of this deep fissure constitute the island of Reil.

In the course of the development, then, we find neurones originating from the cells that lined the central tube. Masses of nerve cells in the cord constitute a continuous structure. In the cerebrum and cerebellum they show an exuberant growth in comparatively isolated regions, separated from other cell masses by regions of white matter. From these cells the axones grow out for long distances to the sense organs and to the muscles on the peripheral side and to the other cell masses in central structures, until sense organ is connected with muscle, and center with center throughout the organism. The problem of understanding the nervous system is very largely one of tracing these connecting paths from sense organ to center, and from center to center within the entire system.

The Conduction of the Nerve Impulse. — The function of the nervous system, regarded most generally, is to make possible the action of the animal. This it does by providing a path by which the results of stimulations of the sense organs may be propagated to the muscles and cause them to contract. These contractions produce the movements which in sum constitute the behavior of the animal or man. An important problem in connection with the function of the nerves is what passes along the nerve in what we call the nerve impulse. Early theories assumed on the one hand that it was a chemical process after the analogy of the burning fuse, and on the other that it was purely electrical. Five experimentally determined facts must be recognized by any theory to have the theory accepted.

1. The rate of the impulse in mammals is from 80 to 120 meters a second in long medullated nerves and from 0.8 to 1.8

meters for the fibers of the autonomic system. This is so slow as to make it impossible to regard the nerve impulse as an ordinary electric current.

2. The impulse is followed by relatively little fatigue. For about 0.015 of a second after each wave passes, the nerve cannot be stimulated. This is the *refractory period.* Aside from this brief interval of incapacity to act after each impulse passes, stimulation of the nerves for hours does not decrease their capacity for response.

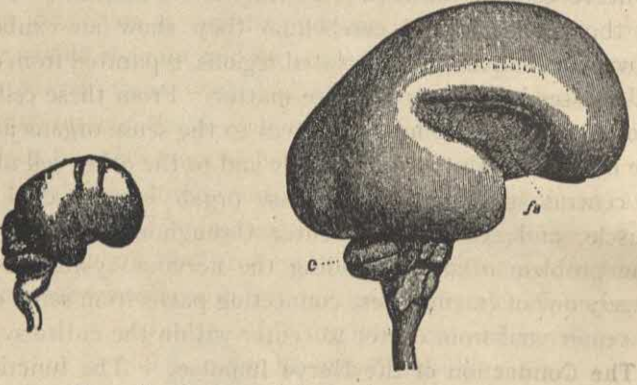

FIG. 17. — Shows development of the hemisphere, the left figure at three months, the right at six months. *fs* is the fissure of Sylvius; *c*, the cerebellum; *m*, the mid-brain. (From Kölliker.)

3. It uses very little oxygen, although oxygen is required if the nerve is to conduct.

4. Carbon dioxide is given off, but at a relatively slow rate.

5. Only extremely small amounts of heat are produced by the action of the nerve.

The development of means for amplifying small electric currents and measuring currents of very slight duration has increased very greatly our knowledge of the electrical phenomena that accompany the nerve impulse. A first result of Adrian and Lucas was to prove that a wave of negative potential traveled along the nerve at the rate of the nerve impulse. This was shown always to be of the same intensity no matter how strong or weak the initiating stimulus. If passage along the nerve was blocked by cooling or by anæsthetizing, when the impulse passed at all, the current always showed the same voltage. This was known as the *all or none law.* If this were the only story, it would make very difficult understanding how we perceive differences in the strength of external stimuli. More recent investigations by Adrian, Gasser, and others prove that any impulse is made up of a number of successive waves, and that the rate at which these succeed each other varies with the strength of stimulation. When the stimulation is faint, these waves may follow each other at as low a rate as five per second. When the stimulus is strong, they may recur as often as 150 per second. These values have been proven to hold both for sensory and for motor nerves. It seems highly probable that the rate of succession of the waves determines the strength of the sensation.

The Nature of the Nerve Impulse. — These facts prove definitely that neither of the simple earlier hypotheses is satisfactory, but they still indicate that both chemical and electrical processes are involved in the impulse. Possibly the most acceptable theory that we have at present was suggested by R. S. Lillie. This assumes that the nerve impulse is due to a chemical change excited by the stimulus. This starts short electrical currents as does the chemical action in a battery. These electric currents in turn produce new chemical changes at a short distance which again give rise to currents. Many more details need to be supplied, but there is fairly general agreement that both chemical and electrical activities are involved in the nervous impulse. Like all chemical reactions these chemical changes in the nerve have electrical effects and accompaniments. The chemical changes are comparatively slight but suffice to induce the electric currents. Whatever the character of the nervous impulse, it constitutes the essential activity of the neurone, and as it travels from sense organ to center or from center to muscle, the sensations or movements are made possible.

The Course of the Impulse. — The specific activities of the nervous system depend upon the course that the impulse takes through it. The simplest form of nervous response that an organism makes is called the reflex. It is the type of all nervous action. The winking of the eye, the withdrawal of the hand when burned, are primarily reflexes. The explanation of the reflex is to be found in the presence of chains of neurones between the sense organ excited and the muscle producing the response. The simplest reflex involves at least two groups of neurones, a sensory and a motor. It can be seen most clearly in the spinal cord. If a finger be pricked, an impulse passes to the cell body of a neurone in the spinal ganglion, thence along the axone to the motor cell in the anterior gray horn of the cord, whose activity causes the muscles of the arm to contract and to draw back the hand. That these reflexes depend upon the nervous connections in the cord and upon these alone is evident from the fact that they persist in the lower animals after the cord has been cut off from the brain, but cease if the cord is destroyed or the nerves that lead to or away from it be severed. In a frog, whose head has been removed or whose cord has been cut in its upper part, the reflexes persist. Stimulation of the skin causes movements of the members. Even a dog may be kept alive after its brain has been removed, and this ‘ spinal dog,’ as it is called, carries on the reflex activities of the lower body in a perfectly normal way. When stimulated on the skin of one foot, that foot will be drawn back. If the intensity of the stimulation be increased, the member on the opposite side is moved, and as the stimulation is still further increased in intensity, movements are executed by muscles up and down the trunk at many different levels. In the frog, for example, if a bit of paper be dipped in acid and put upon the skin of the right thigh, the first effect is to bring the right foot up in an attempt to wipe away the paper; if that foot be held, the other will be brought across and remove the stimulation.

The Spinal Cord

Reflexes in the Cord. — To understand these reflexes as well as most of the activities of the lower part of the body, it is necessary to sketch the structure of the spinal cord. The cord contains an inner mass of gray matter, somewhat like an H in shape when seen in cross section, surrounded by columns of white matter. The extensions of the gray matter are known as the horns; the backward extension, the dorsal horn, and the anterior extension, the ventral. The white matter between and around the horns comprises the columns. The dorsal horns receive axones from the spinal ganglia. The anterior horns contain large motor cells whose axones send impulses to all of the muscles. All acts, voluntary as well as reflex, are directly caused by the excitation of these anterior horn cells. The white matter is divided by the dorsal and ventral horns into three columns, the dorsal, the lateral, and the ventral. In the simple reflex the sensory impulse is received by the neurones in the dorsal root ganglion (C^2 in Fig. 18), thence is transmitted by their axones across the gray to excite the ventral horn cells (C^1 in Fig. 18). The sensory neurones also send collaterals to the ventral horn of the opposite side. These collaterals may connect directly with motor cells or they may come into contact with the dendrites of intermediate or commissural neurones, whose axones make the connections with the anterior horn cells.

The point of contact between the end brush of one neurone and the dendrite of another is known as the *synapse*. Here the impulse must pass from one neurone to another and we know from the time required that transfer across this gap meets more resistance than over a similar distance within the neurone. Synapses differ in the degree of resistance they offer. This difference in resistance is assumed to determine the course of the reflex. Thus the synapses to the motor neurones which excite the muscle of the side of the body stimulated are most permeable, and in consequence the first and usual movement is made by the member on the same side. It is only when the stimulus becomes stronger that the member opposite moves. The neurones in the spinal ganglia also send collaterals up and down in the cord, which connect directly or through commissural neurones with the motor neurones at various levels (Fig. 19). These carry impulses from the level at which they enter to groups of muscles whose nerves go out above and below. All cord reflexes are determined by the connections between the axones of cell bodies in the spinal ganglia and the motor cells in the ventral horn, and the openness of synapses between them.

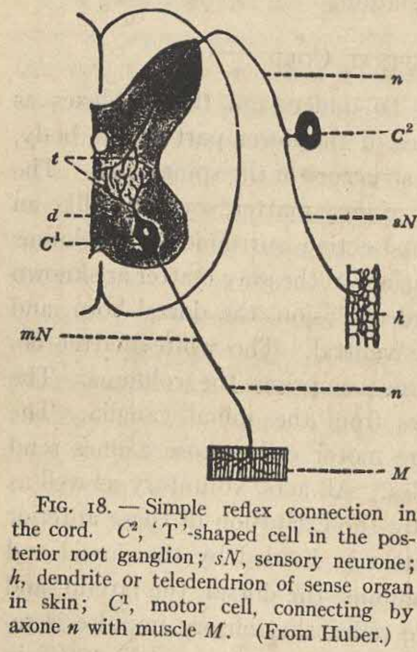

FIG. 18. — Simple reflex connection in the cord. C^2, 'T'-shaped cell in the posterior root ganglion; *sN*, sensory neurone; *h*, dendrite or teledendrion of sense organ in skin; C^1, motor cell, connecting by axone *n* with muscle *M*. (From Huber.)

Tracts in the Cord. — In addition to its reflex functions, the cord provides the only path of conduction between the body and the brain. These long conduction paths are divided into the sensory or afferent and the motor or efferent. The

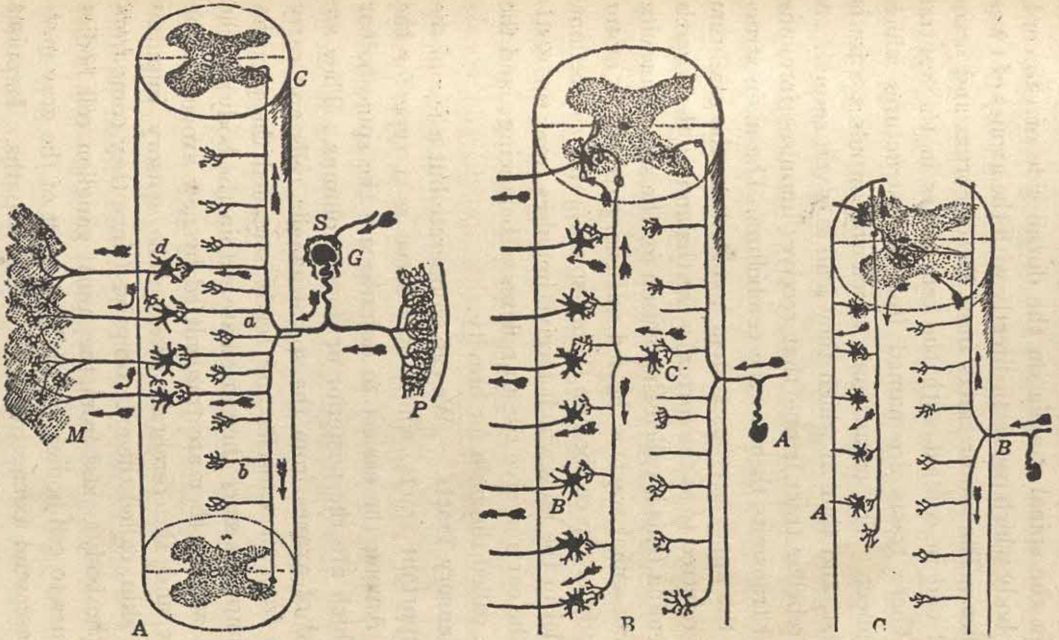

FIG. 19. — The connections in the cord by which impulses spread to different levels. A shows the connections by which impulses spread immediately from the sensory to motor neurones on the same side; B shows the connections made through an intermediate or commissural cell (*C*) to motor neurones of the same side; C shows paths by intermediate cell to opposite side. (From Cajal.)

sensory paths are composed of fibers which are axones of cell bodies in the spinal ganglia on the dorsal side of the cord, or a cell body which connects directly with the axones of those cell bodies. The motor tracts from the cerebrum and brain stem all end in contact with the cell bodies in the ventral horn. These tracts are named from the structures which they connect. The organ from which the impulses arise is given first, and that to which they lead is given second. A spino-cerebellar tract is one that receives impulses from the cord and transmits them to the cerebellum. The main structures in the upper nervous system involved are the cerebrum (usually referred to as the cortex); the thalamus; the corpora quadrigemina (this is called the tectum for the sake of brevity as in tecto-spinal tract); the red nucleus, part of the motor pathway from the cerebellum (rubro-spinal); the cerebellum, and nuclei in the pons which receive impulses from the vestibule in the ear and give rise to reflexes of balancing; and the medulla, called the bulb for brevity.

The Sensory Tracts. — We can enumerate but a few of the more important tracts, which may serve as a type for the others. Among the easiest to describe are the spino-bulbar tracts which are the posterior or dorsal columns. They are composed of axones from the spinal ganglia cells and carry impulses from the muscles and tendons (called the proprioceptive impulses since they originate within the body) to the medulla, whence they are transmitted by new axones to the thalamus and the cerebral cortex. The sensory impulses from the skin, called the exteroceptive (since they come from outside the body), pass from the spinal ganglion cell bodies over axones to cell bodies in the dorsal part of the gray matter. These send axones over two different paths. Impulses of pain, warmth, and cold are transmitted over tracts in the lateral columns; impulses of pressure are transmitted over paths in the anterior or ventral columns.

Both axones extend direct to the thalamus, whence they are propagated by axones of a new set of neurones to the cortex. It is to be noted that all three paths involve three neurones between sense organ and cortex. The spino-bulbar path crosses in the medulla, the two last mentioned, known as the spino-thalamic, cross in the cord. The spino-cerebellar tracts are found in the superficial dorsal portion of the lateral column. These are axones of cell bodies in the central portion of the gray matter of the cord. The impulses from the spinal ganglion cells are carried to these central cells, whose axones extend to the cerebellum.

Motor Tracts. — Of the descending or motor fibers the most important are the pyramidal or cortico-spinal tracts. There are two pyramidal tracts, the crossed and the uncrossed. The former, always the larger, lies just inside the spino-cerebellar tract and is very close to the dorsal horn of gray matter. The uncrossed pyramidal tract lines the ventral fissure of the cord. Both tracts are composed of axones of cells in the cerebrum, which descend to make connection with the anterior horn cells. They carry the voluntary impulses. The crossed pyramidal is composed of fibers that cross in the medulla; the second or anterior, of fibers that have continued down on the same side but cross in the cord near the level of the cells with which they connect. A bundle of fibers descends from the cerebellum by way of the red nucleus, the rubro-spinal (Fig. 20), and lies ventral to the crossed pyramidal tract. Related in function is the vestibulo-spinal tract that descends on the anterior border of the cord from a nucleus in the pons. It takes its name from the fact that the nucleus from which its fibers come receives axones from the vestibule of the ear, a sense organ for changes in the position of the body. With the rubro-spinal tract, it carries motor impulses for keeping the balance. Other tracts on the anterior surface of the cord are the tecto-spinal and the olivo-spinal. The tecto-spinal is composed of axones from the corpora quadrigemina and carries impulses involved in visual reflexes. The olivo-spinal contains fibers from a nucleus in the medulla. The function of the olivo-spinal tract is unknown. All these tracts are found in the anterior column, although different authorities assign them slightly different positions within the columns. In studying the diagram it should be remembered that each tract is found on both sides of the cord, although for convenience in distinguishing them the sensory tracts are shown on one side and the motor on the other.

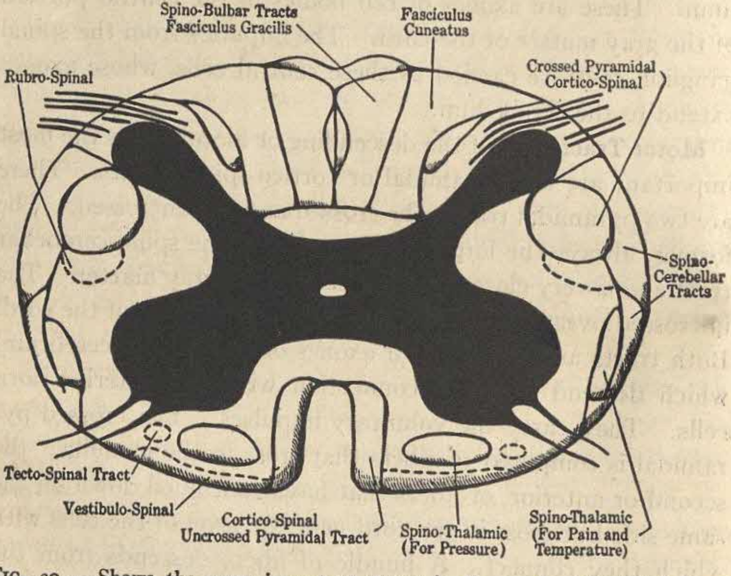
Spino-Bulbar Tracts
Fasciculus Gracilis
Fasciculus Cuneatus
Rubro-Spinal
Crossed Pyramidal Cortico-Spinal
Spino-Cerebellar Tracts
Tecto-Spinal Tract
Vestibulo-Spinal
Cortico-Spinal Uncrossed Pyramidal Tract
Spino-Thalamic (For Pressure)
Spino-Thalamic (For Pain and Temperature)

FIG. 20. — Shows the more important tracts in the cord. (Modified from Villiger.)

The Ground Bundles. — In addition to these long bundles running from cells at one level to others above and below, there are many fibers which make possible the transfer of impulses within the cord. These are numerous at the borders of the gray matter, but also occupy parts of the white area that have been assigned no other function in the above discussion. Probably some of the sensory impressions pass along these fibers on their way to the brain. They go from neurone to neurone, into the central gray and out again, instead of taking the more direct course provided by the long fibers. It should be added that the arrangement of fibers is different at different levels. The pyramidal tracts, for example, are much larger in the upper portions of the cord, as some of the fibers that appear at the upper level leave it to make connections with the ventral horn cells. In fact, the ventral tract cannot be made out at all in the lower regions. The relative amount of white and gray matter also varies at different levels. The gray matter has the greatest extent in the lower lumbar region and in

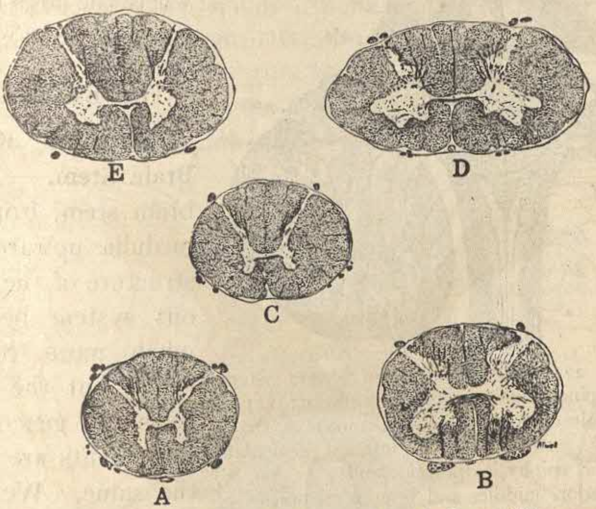

FIG. 21. — Series of sections of the cord to indicate difference in the amount of white and gray and the relative size of the cord at the different levels. *B* is a section through the lumbar enlargement, where the nerves of the legs enter and leave; *D*, a section through the cervical enlargement which supplies the arms. (This figure, together with figures 23, 24, 25, and 31, drawn by Mr. Atwell of the Anatomical Laboratory of the University of Michigan.)

the cervical region, where the large nerves for the legs and arms enter and emerge. The cord as a whole also increases in cross section from below upward, with marked swellings where the large nerves enter. (See Fig. 21.)

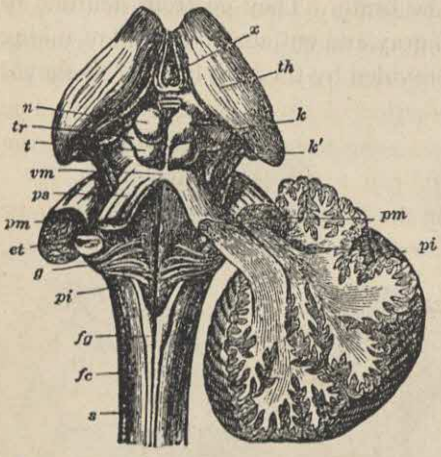

FIG. 22. — Dorsal view of brain stem. *fg*, *fc*, spino-bulbar tracts; *n*, anterior; *t*, posterior pair of corpora quadrigemina; *th*, thalamus; *k*, external and *k'* internal geniculate bodies; *x*, epiphysis (pineal gland); *ps*, *pm*, *pi*, are superior, middle, and inferior peduncles of the cerebellum, which may itself be seen, in part cut away and drawn to one side. (From Wundt.)

THE BRAIN STEM

Functions of the Brain Stem. — In the brain stem, from the medulla upward, the structure of the nervous system becomes much more complicated, but the functions and general arrangements are much the same. We may distinguish three functions of the structures in the brain stem:

1. Fibers massed in well-defined tracts carry the sensory impressions upward and motor impulses downward between cord and cerebrum. These are extensions of the paths in the cord, or tracts that continue into the cord from the brain stem.

2. Masses of neurones provide paths for the reflexes of the head in very much the same way that the cord cares for those of the body. Nerves lead into the nuclei or masses of cell bodies from the special sense organs and from the skin of the head, and motor nerves lead out from them to the muscles of the head just as sensory nerves lead into, and motor nerves go out from, the cord.

3. The brain stem also makes wider interconnections, — the larger nuclei receive large numbers of sensory stimuli from different sense organs and distribute them to muscles in widely scattered parts of the body to make harmonious movements possible. Making the different parts of the body work together is the peculiar function of the nervous system. The coördinations in the brain stem are wider than those in the cord and those of the cerebrum are widest of all.

Important Structures in the Brain Stem. — As a preliminary to discussing the functions of the brain stem, we need to locate certain of the more important nuclei and larger organs. The medulla is practically an enlarged continuation upward of the cord. In the medulla are the nucleus gracilis and the cuneate nucleus which together receive the fibers from the spinobulbar tracts. The fibers from cells in these nuclei cross to the opposite side (decussate) and then proceed upward as the fillet (Fig. 24). Above the medulla in the hind-brain are the pons and the cerebellum. The pons is a mass of transverse or horizontal fibers on the anterior or ventral surface of the brain stem. Within it are masses of cell bodies which receive

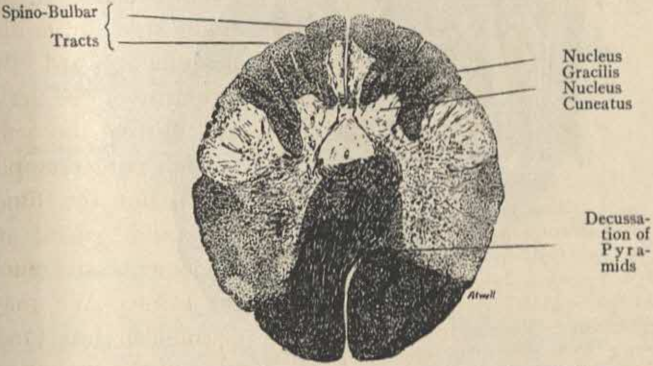

FIG. 23. — Section of the medulla to show the crossing of the pyramidal tracts, a section a little below that shown in Figure 24. × 4.

impulses from the vestibule of the ear and transmit them to the cerebellum and down to the cord. On the dorsal surface is the large outgrowth of the cerebellum, connected with the brain stem by three pairs of strands of fibers, the cerebellar peduncles. Between the remainder of the brain stem and the cerebellum is a large opening, an expansion of the spinal canal, known as the fourth ventricle.

Above the cerebellum, on the dorsal surface of the original mid-brain, are four small eminences containing gray matter within, the corpora quadrigemina. At the level of the corpora quadrigemina and on the ventral side of the remnant of the original tube, which is here more nearly its original size and known as the aqueduct of Sylvius, is the red nucleus. These structures can be seen in Figure 31. The lower corpora quadrigemina are reflex centers for auditory impressions, the upper or anterior for impressions from the eye. The red nucleus is a way station for descending or efferent impulses from the cerebellum. Above the mid-brain the aqueduct enlarges to

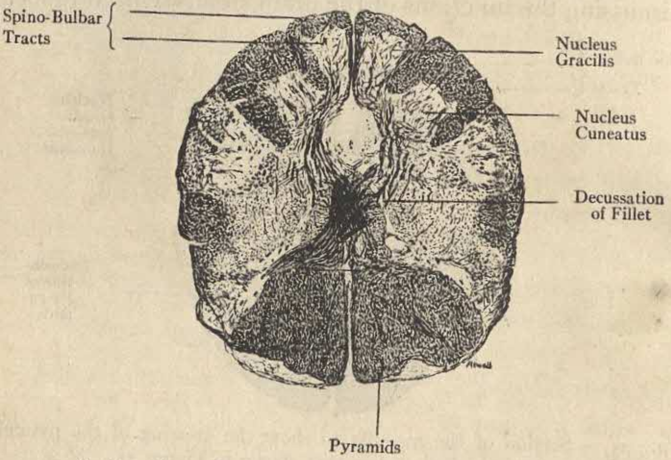

FIG. 24. — Section through the medulla to show the crossing of the sensory fibers, the axones of cells in the nuclei gracilis and cuneatus. × 4.

form the third ventricle, an opening widest in its vertical dimensions. About this is the tween-brain. The lateral walls of the third ventricle are formed by the thalamus.

THE PATHS IN THE BRAIN STEM

The Paths between Cord and Cortex. — Nerve currents from the sense organs of the limbs and trunk may reach the cortex by two distinct paths. The first, which probably carries only the proprioceptive impulses from muscles and other deeper lying tissues, is provided by the dorsal spino-bulbar columns. Axones of cell bodies in the spinal ganglia ascend by these columns to the nucleus gracilis and nucleus cuneatus in the medulla. Here they come into contact with dendrites of other neurones whose axones cross to the other side and then proceed up the central portion of the brain stem to the thalamus. Thence a third set of neurones carries the impulse to the cortex. The crossing can be seen in Figure 24,

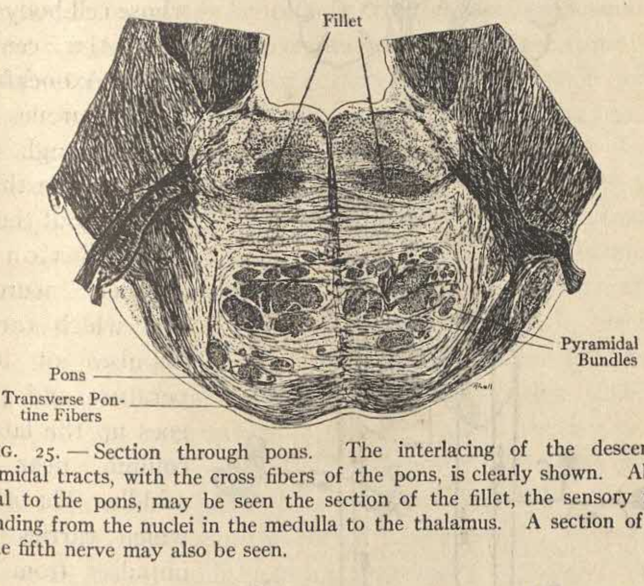

FIG. 25. — Section through pons. The interlacing of the descending pyramidal tracts, with the cross fibers of the pons, is clearly shown. Above, dorsal to the pons, may be seen the section of the fillet, the sensory fibers ascending from the nuclei in the medulla to the thalamus. A section of part of the fifth nerve may also be seen.

the entire path in Figure 26. Impulses from the external skin apparently travel by other spinal neurones whose axones enter the central gray of the cord and make connections with dendrites of a second neurone whose cell body lies near the central canal. Axones from these neurones extend through two tracts to the thalamus without the intermediation of another neurone. One which carries impulses of temperature and pain goes up the lateral column near its middle. The other, which carries the impulses from the organs of the mechanical sense, contact or pressure, extend up the anterior column. Both tracts are in the column opposite that of the ganglion cell from which they enter the cord.

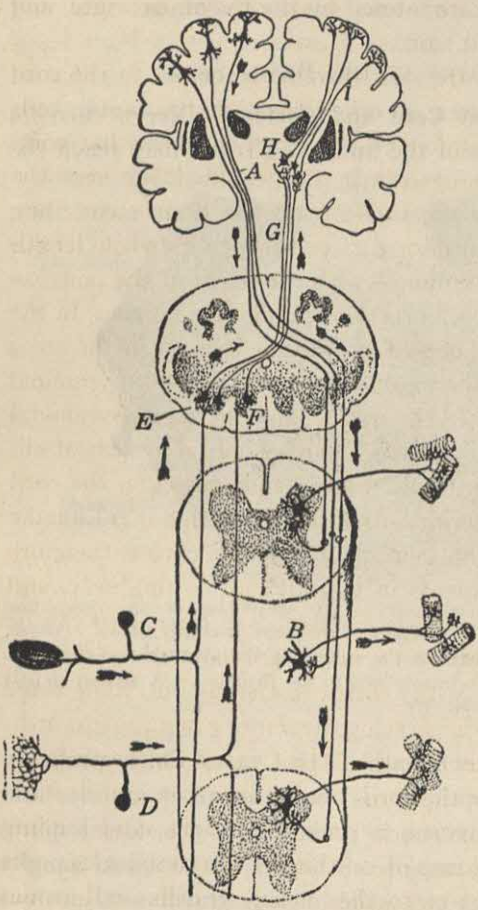

FIG. 26. — Showing schematically the ascending and descending tracts between cord and vortex. *A*, pyramidal tracts; *B*, motor cell; *C*, *D*, sensory cells; *E*, *F*, nuclei cuneatus and gracilis; *G*, central sensory path; *H*, thalamus. Only the sensory path by the posterior columns is indicated. The arrows indicate the direction of the impulse. (From Cajal.)

When part of the cord is destroyed by disease, a patient may lose the sensations of pain and temperature and still retain sensations of contact, or lose sensations of pressure and retain temperature and pain.

Voluntary impulses are carried from the cortex to the cord by the pyramidal tracts, so-called because the motor cells in the cortex are pyramidal in shape. The fibers that compose them are axones of cells in the frontal lobes near the central fissure. After the tracts enter the brain stem, they can be traced on its anterior surface through its whole length except where they intermingle with the fibers of the pons, as can be seen in Figure 25 (a section through the pons). In the medulla, part of the fibers cross, as can be seen in the cross section (Fig. 23). These constitute the crossed pyramidal tracts already noticed in the cord. The uncrossed pyramidal tract, which is usually smaller, and may not be present at all, continues down the anterior column and crosses in the cord at the level of the anterior horn cells with which it is to make connection. The right hemisphere of the cortex therefore always arouses movements in the left half of the body, and *vice versa*. The course of these descending fibers also can be seen in Figure 26. Only two neurones are required to transmit the motor impulse from the cortex to the muscle, while three at least are concerned in carrying the sensory impulse upward.

Roots of Cranial Nerves and Their Central Connections. — The brain stem is like the cord, also, in its second set of functions, receiving sensory fibers and impressions, and sending out motor nerves and impulses. Unlike the continuous series of cells in the cord, the cell bodies whose dendrites and axones constitute the so-called cranial nerves are grouped in isolated masses of cells along the brain stem, the nuclei of the cranial nerves. From these nuclei, connections are made with each other, with the cerebellum, corpora quadrigemina, and cortex. The location and connection of the parts would require more space and the knowledge of more details of anatomy than can be given in so brief a statement. It may be said in general that there is some approximation to the arrangement of the spinal cord in that the motor nerves frequently are anterior to the ventricles, while the sensory nuclei are more lateral or posterior. These sensory and motor nuclei also have connections with the cortex similar to those of the cord.

Connections of the Auditory Nerve. — We may trace the course to the cortex of some of the more important sensory nerves of the head. The eighth nerve, or nerve of hearing,

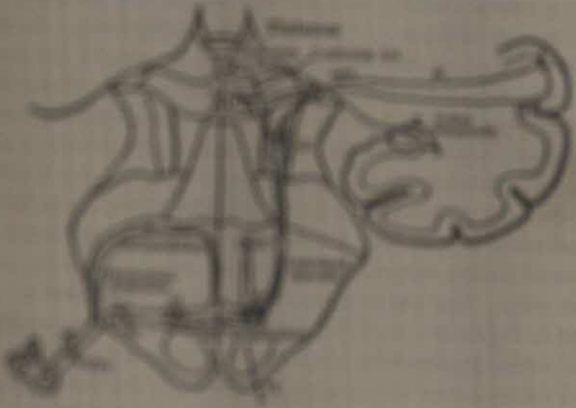

FIG. 11. — The central connections of the cochlear branch of the eighth nerve, the nerve of hearing. [illegible]

axones of the neurons from the cells in the spiral ganglia in the ear (Fig. 15). These connect with the dendrites of cells in the root of the eighth nerve at the level of the pons; from these, new neurones carry the impulse to the superior olives on both sides, and thence by two other neurones it goes forward to the internal or median geniculate body, a part of the thalamus, and to the posterior corpora quadrigemina. From the geniculate body, one set of neurones carries the impression forward to the cortex where hearing takes place. In the posterior corpora quadrigemina reflex connections are made with eye and head muscles.

The Optic Tracts. — The retina, the sensitive part of the eye, embryologically, is a part of the brain which has grown to the surface. Axones from the large ganglion cells (see pp. 128 f.) unite to form the optic nerve. The optic nerves from the two eyes come together on the under surface of the midbrain, in the optic chiasma, and then separate again beyond. In the chiasma there is a partial crossing. Fibres from the outer half of each retina merely bend in the chiasma and each goes to the half of the brain on the same side. Fibres from the inside of each retina cross at the chiasma and proceed to the opposite side of the brain. The result is that fibres from the right side of each retina are projected on the right brain, those from the left side of each retina are projected on the left brain. So images from the same object on the two retinas arouse an impulse in the same hemisphere. From the chiasma the optic neurones go to the external geniculate body and to the so-called pulvinar of the thalamus on the one hand, and to the superior corpora quadrigemina on the other. In the thalamus connection is made with another neurone whose axone, in turn, proceeds to the surface of the median occipital lobe, the cortical area for vision. The fibres that go to the corpora quadrigemina excite the visual reflex in head and body, turning the eyes, moving the head, and holding the body erect.

Cutaneous and Motor Connections of the Head. — The fifth nerve, in part a sensory nerve for impressions from the skin and other tissues of the head, has its cells in a large gan-

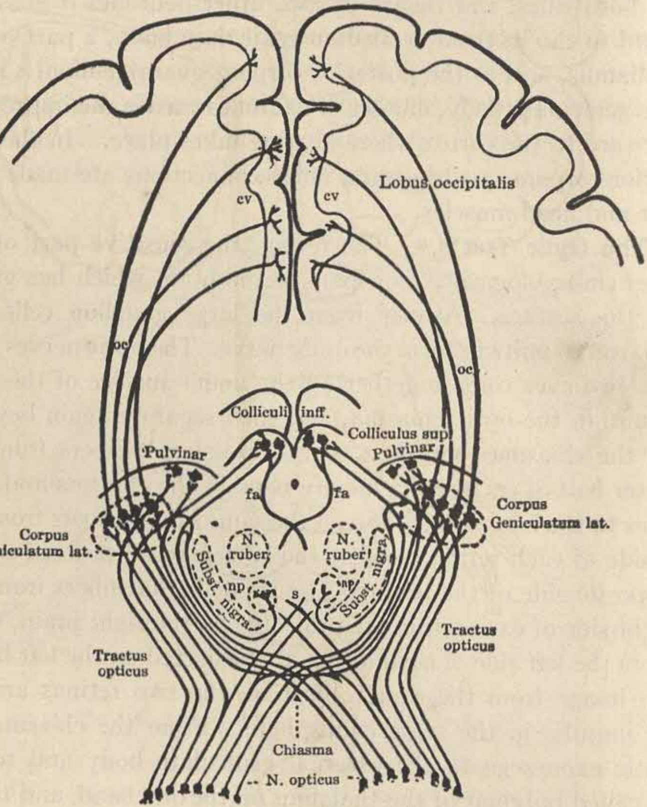

FIG. 28. — The central connections of the optic nerve. From the neurones in the eye the axones that form the optic nerve extend, after partial crossing in the chiasma, to the external geniculate body where connection is made with a second series of neurones which carry the impulse to the median surface of the occipital lobe. Other axones connect with the pulvinar of the thalamus and with the anterior corpora quadrigemina (*Colliculus sup.*). From the latter impulses are carried to the roots of the oculo-motor nerves by the path *fa*, through which reflexes are aroused. (After Bechterew.)

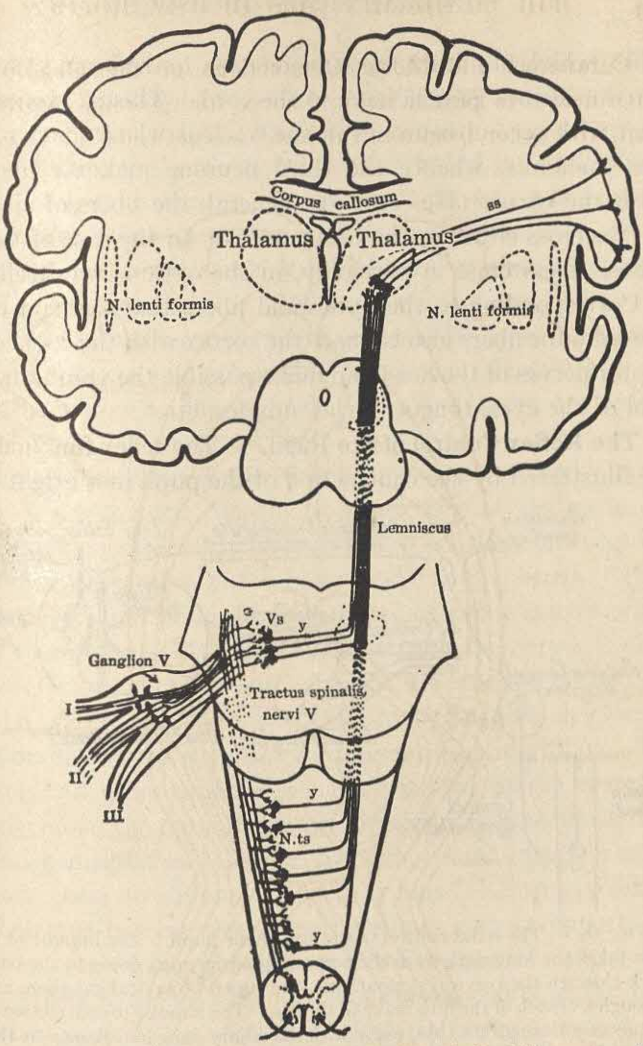

FIG. 29. — The ascending or sensory connections of the fifth nerve. The relations are very similar to those of the dorsal roots of the cord. The receiving neurones have cells in the ganglion (*Ganglion V*), send axones to the sensory nuclei, *Vs*, which correspond to the nuclei of the medulla for the spinal nerves, whence the new neurones connect with a third layer of neurones whose cell bodies are in the thalamus and which carry the impulse to the cortex. (From Rauber-Kopsch.)

glion, which has much the same relation to the brain stem that the dorsal root ganglia have to the cord. Thence axones connect with second neurones in the nucleus whose axones go to the thalamus, whence the third neurone makes connection with the cortex (Fig. 29). In general, the fibers of all these nerves cross either in the brain stem or, in the case of the eye whose fibers cross in part only, in the optic nerve itself.

Corresponding to the pyramidal fibers that descend to the cord, motor fibers also connect the cortex with the roots of the motor nerves of the head and make possible the voluntary control of the eyes, tongue, facial muscles, etc.

The Reflex Control of the Pupil. — The reflex function may be illustrated by the contraction of the pupil in a bright light.

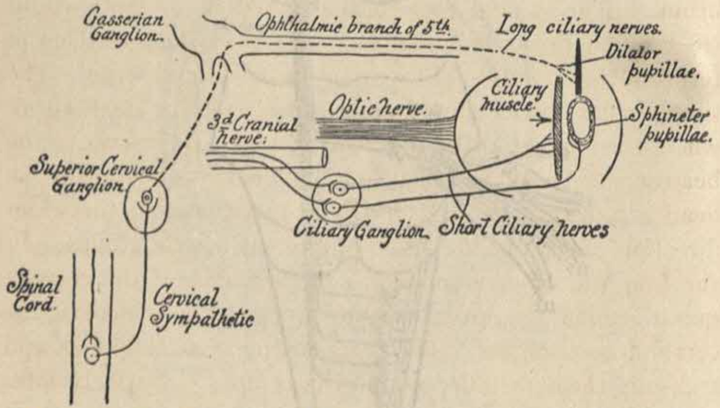

FIG. 30. — The reflex control of the size of the pupil. The impulse of dilatation takes the long path from the corpora quadrigemina down to the cord and back through the cervical sympathetic, the superior cervical ganglion, and out through a branch of the fifth nerve to the iris. The impulse to contraction makes connection through the third nerve with the ciliary ganglion, thence to the iris. (From Howell's "Physiology," after Schultz.)

As was said above, the optic nerve sends one branch to the anterior corpora quadrigemina. Thence axones proceed to the roots of the third nerve. Neurones there in turn connect with the ciliary ganglion back of the eye, which sends the impulse to the circular muscle in the iris. Strong light causes the sensory impulse to ascend to the corpora quadrigemina, whence it is transmitted by a new neurone to the motor nucleus, thence to the ciliary ganglion, a part of the autonomic system, and from there to the muscle of the iris, whose contraction diminishes the diameter of the pupil (Fig. 30). Similar reflexes are seen in sneezing, which involves the spinal cord as well as the brain stem; in making a wry face at a bad taste, etc. In the medulla are the reflex centers that control respiration, circulation, and other vital functions. The details of the paths, so far as known, may be obtained from any good physiology.

Relations between Brain Stem Coördinations and Cerebrum. — The general coördinating functions of the parts of the brain stem can be understood best if we think of them in terms of the evolution of the brain in the animal series. The simple reflex connection developed first, as in the earth worm, where there is very little difference between the nerves in the head segment and the others. Later the nerve centers of the head become greatly developed and make possible the wider direction of sensory impulses to different muscle groups. In the frog and other amphibians, the analogue of the corpora quadrigemina, the optic lobes, are almost as prominent as the cerebral hemispheres. They receive the visual impulses and transmit them to different muscle groups. Relatively later the thalamus becomes larger and assumes a more important function, receiving impulses from all of the senses and transmitting them to the visceral organs on the one hand, and to the voluntary muscles, on the other. Only in the mammals does the cerebrum grow to great size and take over important functions. It increases in size and importance of function through the mammals to man, where it becomes dominant. In man each of the other parts retains its functions, but they are subordinate to cerebral control.

The Cerebellum. — The cerebellum is apparently closely restricted in its function to the coördination of movements. In its earliest appearance it was connected with the sensory nerves from the vestibule of the ear, which indicate the position of the body as a whole, and has retained that close connection throughout. In addition it receives axones of cell bodies connected with the sense organs in the body of the muscles and tendons, and is connected through the corpora quadrigemina with the retina. In man it also receives fibers from the cortex. From it go fibers to the spinal cord directly and by way of the red nucleus in the mid-brain just below the corpora quadrigemina. It also sends fibers to the motor nuclei of the eye muscles. These make possible the movements of the muscles of the trunk and head.

The Function of the Cerebellum. — The general function of the cerebellum is to coördinate muscular movements, particularly those involved in keeping the balance. The influence is best evidenced by the defects that appear when the cerebellum is injured. Then the body is held erect only with difficulty, if at all, the movements are jerky, the patient staggers when walking, the gait is like that of the drunken man. The balance of the body is not adjusted to the movements of the legs, the patient may lean too far forward or too far back for the immediate position of the body. These effects quickly disappear after the injury, which makes it probable that the cerebellum does more perfectly what other parts of the nervous system can adjust themselves to do when necessary. Recent work makes it probable that certain parts of the cortex of the cerebellum send impulses to definite parts of the body. Streeter has established the localization by tracing the fibers, Bárány by a study of the effects of injuries of the cerebellar cortex and by direct stimulation of its surface. It is probable that the nerve currents from the various organs, skin, muscle, the vestibules of the ears and the eyes, which give a knowledge of position, are here united and coördinated and then sent out to the muscles, where they produce the muscular contractions that keep the balance. The cerebellum thus serves to bring together the sensory impressions concerned in movement, to graduate them properly, and to send out impulses which shall control the lower reflexes, check some, increase others, and make all work together in proper balance.

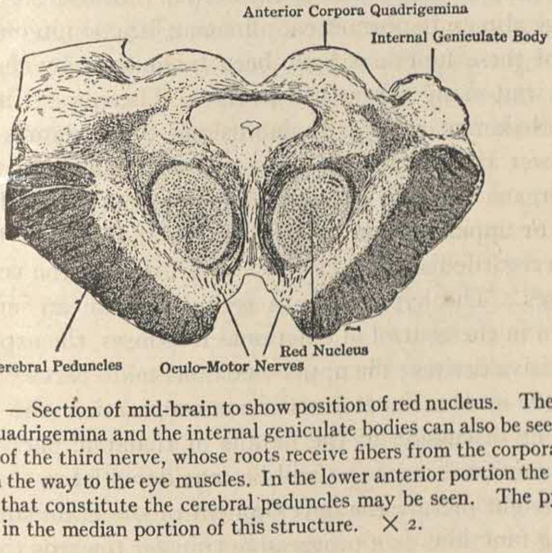

FIG. 31. — Section of mid-brain to show position of red nucleus. The anterior corpora quadrigemina and the internal geniculate bodies can also be seen, as can the fibers of the third nerve, whose roots receive fibers from the corpora quadrigemina on the way to the eye muscles. In the lower anterior portion the descending fibers that constitute the cerebral peduncles may be seen. The pyramidal tracts are in the median portion of this structure. × 2.

Functions of Corpora Quadrigemina. — From the fact that the corpora quadrigemina receive fibers from skin, ear, and eye, and have connections with the motor cells in the cord, as well as with the eye muscles and other muscles of the head, it seems probable that this may be a similar coördinating center. In the lower animals the large development of these organs, as compared with the other regions of the brain, together with direct experiment, makes it seem likely that many of the automatic movements are coördinated here. In man, however, this lower center of coördination has been largely overshadowed in its functions by the cerebral hemispheres, so that it plays a subordinate part. It is the center for reflexes of the eyes, and probably for movements of the head, but neither experiment nor pathology gives much evidence of a coördinating function.

The Functions of the Thalamus. — We have seen that the thalamus is a way station for impulses from the skin and other sense organs in their course to the cortex. In addition it probably has also an important coördinating function in mammals. Some of these functions have been taken over by the cortex in man, but many others still persist. There is distinguished a hypothalamus or lower thalamus and the thalamus proper. The lower thalamus distributes motor impulses to the visceral organs through the autonomic system; the thalamus proper or upper portion sends fiber tracts to the cortex, and may be regarded as more closely concerned with the voluntary responses. The hypothalamus seems to have an important function in the control of emotional responses, the expressions of primitive desires; the upper thalamus takes part in the control of the more rational functions in coöperation with the cortex. The discussion of the details of thalamic participation in the emotional responses will be considered later.

One might picture the development of the brain stem coördinating functions as a progressive transfer towards the upper or cephalic end of the original neural tube of the dominant structure. First to develop as dominant would be the cerebellum. Herrick says that it is originally developed in the lower vertebrates to receive and distribute impulses from the vestibule of the ear, and retains primarily this function of maintaining the equilibrium of the body. In the frog and other amphibians, the dominant coördinating function passes forward to the optic lobes, which correspond to the corpora quadrigemina in man. The cerebellum retains its function of keeping the balance, but is subject to the wider control of the mid-brain. In the bird and lower mammals the thalamus and related lower nuclei of the cerebrum gradually become more important, and the mid-brain is subordinated into a local reflex center. In the higher mammals, and preëminently in man, the cortex assumes complete control, but each of the older coördination centers keeps its primary function, subject to the preëminent cortex. The cerebellum coördinates the balancing movements, the corpora quadrigemina distribute the wider reflexes of ear and eye, and the thalamus distributes the primary stimuli to the primitively reacting mechanisms which give rise to what we call the emotions, and probably has other subordinate coördinating functions.

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CHAPTER III

THE NERVOUS SYSTEM (*Continued*)

In the cerebral hemispheres we come much closer to the problems that primarily concern psychology. Here, we believe, the processes which accompany consciousness in all its forms have their place, and run their course. But for an understanding of the nervous operations themselves this makes no difference. The structures and their functions can be best understood on the analogy of the lower parts of the nervous system. The cerebrum is in its turn just a mass of neurones with their processes, and its functions can be represented as due to the spreading of impulses along paths within it. The problems that meet us here are those that have met us all the way up to this point. The cerebrum constitutes part of the highest and most complicated path by which sensory impressions may pass over to the muscles and excite muscular contraction.

The Functions of the Cerebrum

The Parts of the Cerebrum. — In the cerebrum may be distinguished three sets of structures. On the surface there is a relatively thin layer of gray matter, a number of layers of neurones with connecting processes, — the cortex. This outer coat has a large area because of the great number of fissures and folds that are found on its surface. These are much more numerous and deeper in man than in the animals. Below the cortical gray the interior is largely filled with white matter, — masses of fibers that run from the cortex downward to the brain stem, from one part of the hemisphere to another, or from one cortex to the other through the corpus callosum and the commissures. At the base of the cerebrum are found other masses of gray matter, the corpora striata. These are divided into a number of nuclei by the fibers that descend from the cortex to the brain stem, the corona radiata. These ganglia apparently coöperate with the thalamus in serving as paths for some of the fundamental responses, autonomic and voluntary. Regulation of temperature and of other metabolic functions has been ascribed to them. When these are diseased in man, certain tremors are likely to appear.

Lobes of the Cerebrum. — The cerebrum is divided by the median fissure into two hemispheres. Each hemisphere for convenience of reference has been marked off into five lobes. Three fissures or folds in the cortex have been selected as boundaries. The most prominent is the fissure of Sylvius. It is on the side of the cerebrum and runs backward and upward from a point under the skull approximately level with the eyebrows. Although the edges of this fissure are in contact, there is usually quite a hollow below the surface, and its walls and bottom have a considerable area. This area is called the Island of Reil and is usually spoken of as one of the five lobes. From a point near the middle of the Sylvian fissure, a second prominent fissure extends upward and a little backward to the median fissure and often shows on the median surface of the hemispheres. It never extends quite to the fissure of Sylvius, but is separated from it by a fold or gyre. The fissure itself is the central fissure, or fissure of Rolando. The central fissure marks off the frontal lobe from the parietal behind it, and the Sylvian fissure separates the frontal and parietal from the temporal lobes. The parietal lobe is bounded at the back by the occipital lobe. The line of division is distinct on the median surface of the cerebrum, the so-called parieto-occipital fissure, but no boundary is to be noted on the lateral surface. The line of demarcation between the parietal and temporal lobes is a line continuing the Sylvian fissure. It should be stated that the fissures and gyres or convolutions are not identical on all brains. The Sylvian fissure can be recognized in all, the central fissure in practically all, but the others are subject to considerable variation. The five lobes, the frontal, temporal, parietal, and occipital, together with the Island of Reil, are the parts into which the cerebrum is divided. The two important reference lines are the fissures of Sylvius and Rolando. They can all be made out in the diagram (Fig. 32).

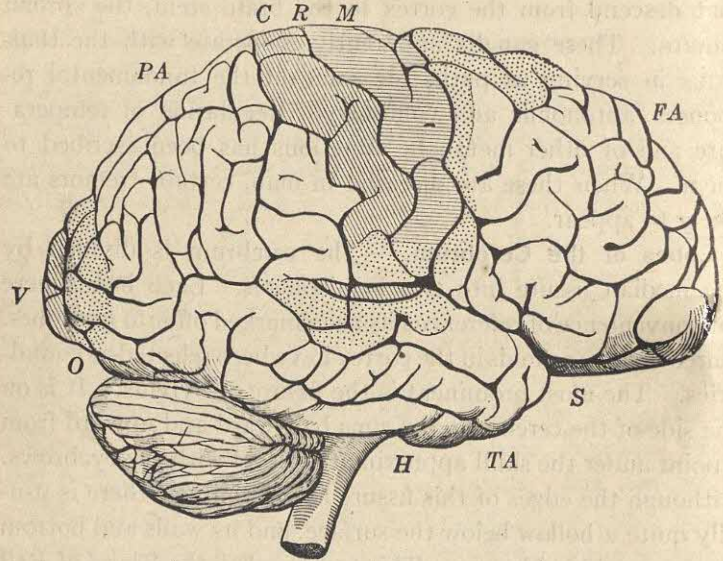
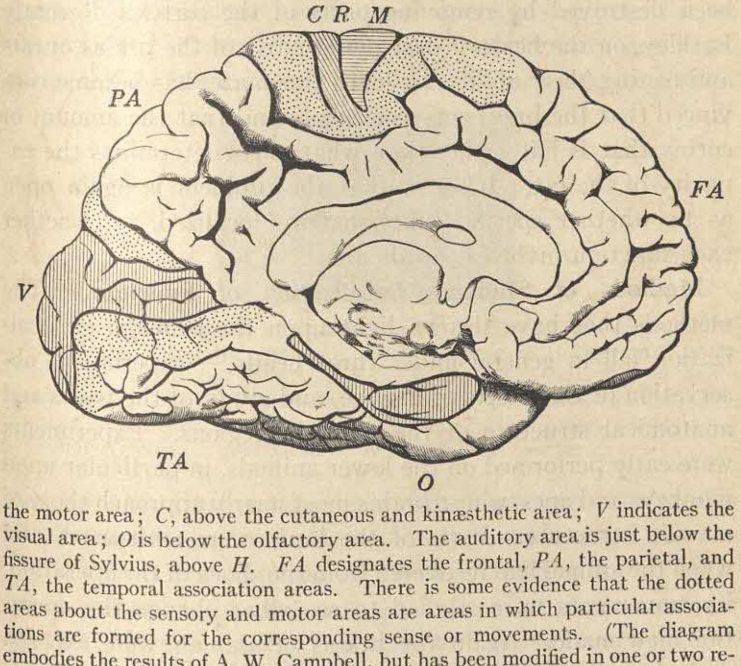


FIG. 32. — Localization of cerebral functions. The figure above shows the outer surface of the right hemisphere; the one on p. 65, the mesial surface of the left hemisphere. In both figures the motor areas are marked by horizontal shading, the sensory by vertical shading, while the associatory areas are unshaded. The doubtful or partially sensory and motor areas are dotted. *S* is opposite the fissure of Sylvius; *R*, above the fissure of Rolando. On the mesial surface the parieto-occipital fissure is just above the shaded portion marked *V*; *M* is above

While the functions of the cerebrum stand in closest connection with thought and with mental operations in general, the development of a knowledge of the exact connection between the parts of the cerebrum and mental action has been a matter of very slow growth. The phrenologists, Gall and Spurzheim, began it, but their methods were very inaccurate and their conclusions so much mixed with speculation that they deserved and received little credence. After their time, in the third decade of the last century, through the work of Flourens, the opinion became fully established that the cerebrum acted as a unit, and no special function could be assigned to one part rather than to another. It was not until 1867 that Broca's studies of aphasia gave a suggestion that each part of the cortex has a special function, and led to studies



the motor area; *C*, above the cutaneous and kinæsthetic area; *V* indicates the visual area; *O* is below the olfactory area. The auditory area is just below the fissure of Sylvius, above *H*. *FA* designates the frontal, *PA*, the parietal, and *TA*, the temporal association areas. There is some evidence that the dotted areas about the sensory and motor areas are areas in which particular associations are formed for the corresponding sense or movements. (The diagram embodies the results of A. W. Campbell, but has been modified in one or two respects to agree with the results of Flechsig and Cushing.)

of localization. For fifty years the dominant belief has been that each function has a definite place in the cortex, and each area in the cortex a definite function. Neverthless there have been individuals who were somewhat skeptical of the claims to absolutely definite localization. Marie objected to the definite localizations of speech, Franz showed great power of recuperation in monkeys whose capacity for movement had been destroyed by removing parts of the cortex. Recently Lashley, on the basis of destroying parts of the brains of rats and testing their ability to learn the maze, has become convinced that the brain acts as a whole and that the amount of cortex that is left rather than what parts determines the capacity of the rat. It seems that the problem is again open as to whether specific functions are localized, or whether each function involves a wide area.

Methods of Studying Localization of Function. — The methods that have thrown light upon the problem of localization fall in general under three heads, — experiment, observation of the effects of disease, and study of the paths and anatomical structure of the different regions. Experiments were early performed on the lower animals, in particular upon monkeys and apes, whose brains most nearly approach those of man in structure. Parts of the brain were extirpated, and when the animal had recovered from the shock of the operation, its movements were studied to see what change the operation had made. Again the brains of animals were exposed and the cortex stimulated by electric currents and the resulting movements were noted. In man, cases of sensory or motor defects were studied carefully and then the brain of the patient examined after death and the two series of results brought into connection with each other. It was found, for example, that a man who showed one sort of difficulty in speech would have lesions in one part of the brain, a man with another sort of defect would have another area diseased. Careful study of many cases has shown that there is a close relation between the two. The anatomical methods have resulted in tracing paths of connection between many areas, and have shown some relations that could not be demonstrated by either of the others. Especially noteworthy has been the result of tracing paths as they develop in the embryo or through the brains of increasing complexity in the animal series. These simpler paths make possible the detection of connections that would be overlooked in the fully developed or in the complex brains. It has also been demonstrated that there is a close parallel between the function of an area in the cortex and the arrangement of cells and fibers. Thus, the visual area is characterized by two light bands, one of them much wider than in other areas. It is called the striate area because of these stripes. Areas with other functions are nearly as characteristically marked (Fig. 33).

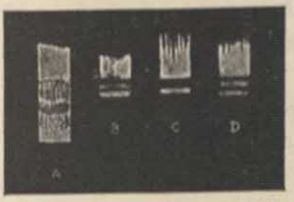


FIG. 33. — Differences in general appearance of different areas of the cortex, as seen by the naked eye. Shows relative differences in thickness and in the distribution of cells and fibers. A, motor cortex; B, sensory from posterior central gyrus; C, visual cortex from calcarine region; D, auditory center, temporal lobe. (Redrawn after Elliot-Smith. From Ranson's "Anatomy of the Nervous System." Published by W. B. Saunders Company.)

The General Function of the Cortex. — While the cortex has been accepted as the most important part of the brain in man for the control of behavior, and as probably most directly associated with consciousness, still its function is closely related to that of the rest of the nervous system. Like the cord or the thalamus, it is a region in which sensory impulses are transferred to motor regions and distributed to different muscles. Fibers may be traced to the cortex from each of the sense organs, and from the cortex axones grow out to make connection with lower motor centers, from which other axones grow directly to the muscles. All are agreed that definitely isolated areas of the cortex are connected with each of the senses, and that other areas are the points from which impulses go to muscle groups. Two views may be said to be striving for acceptance with reference to the other functions. The older would assert that there are fairly definite sensory and motor regions. These are called the projection areas, since the relation between sense organ and cortex and cortex and muscles is similar to the relation between a lantern slide and the picture it projects upon the screen. Two views may be said to be struggling for acceptance concerning the way the projection areas are brought into connection with each other and the resulting more complicated functions of the brain. The older theories would assert that there were fairly definite paths of connection between the sensory and the motor areas and that we might hope to determine the path that was involved in any type of behavior or thought. The other and newer theory assumes that there are great varieties of combination which may produce the same act, that any act is determined by the interaction of wide areas which influence each other mutually. Both would admit that the parts between the projection areas make possible these acts and they are called association areas. The two parties to the controversy differ mainly as to the definiteness of the areas that are involved in any response. We must distinguish the different parts.

The Motor Areas. — The motor areas are most accurately determined. They are in the frontal lobe just in front of the central fissure, extending from near the fissure of Sylvius upward to the median fissure and over upon the median surface. The muscles of the head and face are represented upon the lower portion, the areas for the arms, the legs, and the trunk are found in order as one proceeds upward. Since the descending fibers cross, the right half of the body is controlled from the left brain, and *vice versa*. The details can be made out with greater clearness from the diagram than from any description. Some of the movements can be localized with great definiteness in a single animal. The thumb has a separate area for the control of its movement, and the same may be said of other important organs and muscles. These areas have been determined, in part by a study of the paralysis that comes with disease and in part by noting the movements that result from stimulating different portions of the motor cortex in animals. Then, too, in the motor areas are certain peculiar cells, the giant pyramidal cells, whose axones can be traced down the brain stem and cord as the pyramidal tracts. Most important of all is the fact that it is possible to stimulate the motor cortex of a man whose skull has been opened for operation. In a very striking operation by Dr. Cushing, the skull was opened over a large area during primary anæsthesia, then the patient was permitted to return to consciousness and the cortex stimulated while he was in a condition to report on what happened. The results obtained in this way were sufficient to convince the world of science that the motor part of the cortex is restricted to the frontal lobe rather than extending backward across the central fissure, as was thought a few years before.

The Sensory Areas. — The sensory areas are widely distributed. The area for touch is found in the parietal lobe just behind the central fissure. The localization of the different parts of the body are on approximately the same level as the motor area for the same part. Movement or proprioceptive sensations — impressions received from sense organs in muscle and tendon — are localized a little farther back and with the same general distribution. The auditory area has been located in the posterior portion of the temporal lobe, in the convolution adjoining the fissure of Sylvius, and probably extending over upon the wall of that fissure, the Island of Reil. Each ear probably sends fibers to both hemispheres, so that both sides of the brain in this region of the temporal lobe must be destroyed if the patient is to be centrally deaf.

The Visual Area. — The region for vision is very accurately determined. The immediate receiving area is on the posterior part of the median surface of the cerebrum along the calcarine fissure and laps over slightly on the posterior lateral surface. The area is known from tracing the optic fiber tracts, from the degenerations that are found in individuals who have been blind all their lives, and by study of the effects of injury to this portion of the cortex. As was seen in the preceding chapter, there is a partial crossing of the fibers at the chiasma, so that the left half of each cortex receives fibers from the left half of each retina. In consequence, if the visual area in the left hemisphere is destroyed, the patient will be blind in the left half of each retina. Since the rays of light cross when projected, this means that he will be blind in the right half of each field of vision.

Studies by Marie, Gordon Holmes, and others of localized destruction of parts of the visual area indicate that the upper half of each retina is projected upon the upper border of the calcarine fissure, the lower half upon the lower border of the fissure. The fibers from the fovea or yellow spot, which is the point of clearest vision, go to the extreme tip of the occipital lobe, the extension of the striate area upon the outer surface of the cortex. Probably fibers from the fovea go to both hemispheres, so that destruction of both occipital lobes in this region is necessary to produce complete cortical blindness. Examination of soldiers wounded in the region of the calcarine fissure showed that they would be blind in certain small areas of the field. A fragment of a shell, *e.g.*, that passed through the upper border of the calcarine fissure would cause a small area below the middle of the visual field (which corresponds to the upper portion of the retina) to become totally blind, while vision elsewhere would be normal.

Cortical Areas for Taste and Smell. — Smell and particularly taste are definitely localized in the cortex, especially in man. The clinical study of these senses has been slight because the senses are so little used for intellectual operations that they are seldom missed when they disappear. What we know of them is derived from tracing the paths. This has been done thoroughly in the lower forms where these chemical senses are well developed. It is fairly well assured that both senses have their cortical projections in the hippocamp region, a fold on the under side of the cerebrum. Taste has been given a special area near the tip of the lower side of the temporal lobe.

While the restricted areas described above are probably the more immediate sensory receiving stations in the cortex, it is not to be assumed that they are the only areas concerned. We have evidence that about both visual and auditory areas are regions that have a related function. Injuries in the temporal lobe near the primary auditory center tend to decrease the efficiency of hearing. Lesions of the occipital lobe near the primary visual areas give rise to partial blindness or inability to interpret or perceive objects. These regions may be assumed to be active in connecting and elaborating the impressions received from the sense in question, rather than serving as the primary receiving centers.

Association Areas. — As will be seen from the diagrams, these projection areas, taken even in the wider sense of the last paragraph, include relatively small portions of the total area of the hemispheres. It was long a question what the functions of the other regions might be. Flechsig may be said to have found the answer. By his method of tracing the course of developing nerve tracts, he showed that masses of fibers led from the projection areas to the other regions of the brain, — that some were connected with few, some with many of these regions. He inferred from this that all of the cortex not included in the projection areas shares in associating the different projection areas; that is, they make possible the transfer of impulses from sensory to motor and from one sensory area to another. Flechsig's theory and other older theories implied that there were fairly definite paths from one area to another and that the same act always took the same course. Recent work by Lashley indicates that in the rat, at least, the areas and tracts are more variable.

Areas Involved in Learning. — Franz had shown that if an animal be taught to run a maze and then have part of the cortex removed the acquired habit is lost. Lashley repeated this experiment and tested rats to determine to what extent removal of parts of the cortex reduced the capacity for new learning. His first results indicated that the time required for learning a maze increased in direct proportion to the amount of cortex removed and without reference to the particular area removed. He argued from this that for learning, the cortex must act as a whole and not be dependent upon any special part. He also found that possibility of acquiring certain habits was not affected by removal of the cortex. The rats could learn to discriminate between light and dark as quickly and in some cases even more quickly if all of the occipital cortex, where vision is known to have its seat, was removed as before the cortex was injured. This was interpreted to mean that the thalamus alone is involved in these simple visual discrimination responses. Estimates of distance required in jumping from one object to another also seemed to be less affected by injuries to the cortex than was perception of form.

Whole *vs.* Part Theory of Cortical Action. — A limitation to the theory that all parts of the cortex are equivalent in their functions was found to hold later by Lashley. Lashley investigated the capacity of rats to discriminate geometrical figures. The rats were placed on elevated stands 20 cms. from a screen in which were two holes. Behind this was a platform on which food might be placed. One hole was firmly closed with a card bearing one figure, the other, having on it the figure to which the rat was to be trained to jump, was held lightly by a spring and would give when struck. When the rat jumped to the rigidly covered hole, he would fall into a net below. The normal animal forms the association between pattern and food very quickly. Rats with one small area on the posterior lateral surface destroyed failed completely to discriminate the patterns. If areas other than this small portion of the striate area be destroyed, the readiness to learn is reduced by large lesions and very slightly diminished by small ones. These results indicate that there is a definite visual projection area in the rat, which includes only a small part of the striate area, which is essential for pattern discrimination. Rats that lack it can learn mazes, estimate distances, and discriminate between light and dark, but cannot tell a square from a circle.

As opposed to the specific localization of pattern discrimination, a less definite localization of hearing and vision may be made. Lashley connected a relatively extended occipital region with vision and Wylie a postero-lateral region with hearing. These areas correlate closely with the capacity for retaining an auditory or a visual habit. The correlation between the amount of this cortex retained and capacity for learning is high, 0.72 for the visual area and 0.63 for the auditory, but no one part within this area seems absolutely essential to the learning. As compared with man the areas of the cortex of the rat seem to be less specific in their functions.

According to Lashley one may distinguish at least three different sorts of areas in the cortex of the rat. One is very specific in that when it is absent a particular function cannot be performed. The small area essential to visual form discrimination seems the only known representative of this type. There are regions specific to one sense. Learning in response to stimuli from that sense varies with the area left intact. Areas for vision and for audition have been discovered that belong in this class. Other areas seem to contribute in some degree to make possible general functions, but to have no determinable special function. These include most of the other portions of the cortex. Learning a maze is more rapid with the intact cortex and becomes slower in direct proportion to the area that is destroyed. The more complicated the problem the more slow is its solution when the cortex is destroyed. Maier found that the rats, when more than 20 per cent of the cortex was removed, could not orient themselves with reference to a bit of food that they had been shown but the path to which had never been traveled directly although they could learn a maze when 40 per cent had been destroyed. In monkeys, Jacobson found that destruction of the frontal lobes had no effect upon the solving of simple puzzle boxes, but did make difficult the opening of a succession of locks.

Lashley, Coghill, Child, and others would abandon the picture of the nervous system as a mechanism to make possible series and groups of reflexes that follow definite paths. In place of it they think of the cortex as a mass of neurones which act as a series of patterns in which different groupings of the mass are possible. The whole as opposed to its parts would be emphasized as primary and any specific acts would be but expressions of pattern arrangements within that whole. No act can be as well performed if any part of the mass is lacking, but no one part is alone responsible for any act.

This is known as the organismic or mass action theory. The older view that each function has a definite location is being modified under the pressure of experiments even by those who retain it in part. How far the pendulum will swing towards an indifference or indefiniteness of function is still a question.

Aphasia. — We can perhaps best indicate the general action of the cortex by a résumé of the processes assumed to be involved in speech. Disturbances in speech were among the first effects of cortical injuries to be studied, and the interpretation of them offers samples of all the theories of cortical action. We can see in the theories excellent instances of the divergences in explanation of brain action. The older theories assumed that speech involved the action of a number of different areas of the cortex in definite order, and that injury to each area would produce an imperfection of speech which

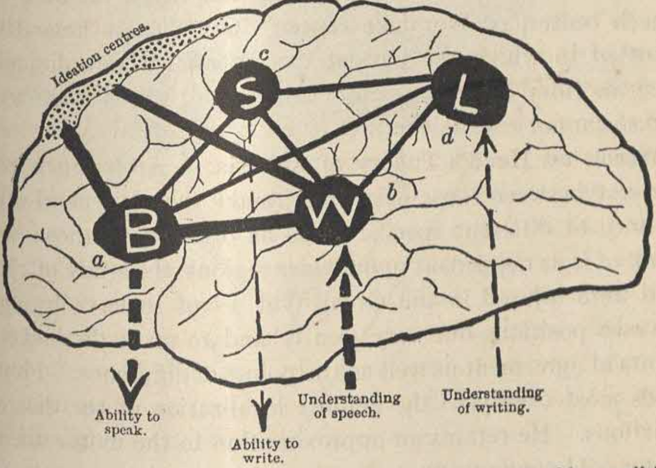


FIG. 34. — Diagram of the speech areas according to the older tradition. B, the Broca area; W, the Wernicke area; S, the area for writing; L, the area for understanding words seen. The newer theories would all disregard the ideation centers marked in the frontal lobe. (From Bing.)

differed from that produced by the injury of any other area. Broca, a French physician, found that a region in the lower portion of the left frontal lobe was destroyed in certain individuals who could think words but could not speak them. This has since been designated the motor speech or Broca center. Later Wernicke found a man who could not understand words that he heard, although he could read aloud, and who after death was found to have an injury in the upper portion of the temporal lobe. This was near but apparently not identical with the center for hearing. It was called the auditory speech center, or Wernicke center. Other cases have been reported in which the patient can speak without difficulty from auditory cues, but cannot understand words when seen, and so cannot read (alexia).

Piéron *vs.* Head's Theory of Aphasia. — After much controversy between those who would make speech depend upon activity of different specific areas as opposed to those who think of it as dependent upon wider regions, the study of cases who were injured in the Great War seems to have brought the two positions out very clearly and to make distinct the points of agreement as well as the points of difference. Piéron holds most closely to the definite localization of the discrete functions. He retains an approximation to the motor speech center. He finds evidence for the existence of a region in the lower frontal lobe (third frontal convolution) and in the neighboring Island of Reil that makes possible the coördination of the muscles involved in speaking. The separate muscles involved in speaking have widely separated areas in the motor area. The center for the muscles of the trunk involved in expiration are high in the motor area, while the point of discharge for the muscles of the face and larynx are low, near the Sylvian fissure. Piéron's theory is that the motor speech center is a region from which single distributive impulses may be sent at the same time or in the right succession to the widely distributed separate areas and so produce the proper timing and coördinated action of each muscle to produce the correct sound. When an injury destroys this region, there need be no paralysis of the separate muscles used in speech, but they cannot be made to coöperate in pronouncing any word. When the injury is slight, certain expressions, such as oaths that have been frequently used, may persist, but ordinary speech be lost. Still slighter disturbances may interfere only with the pronunciation of complex or difficult words, while the easy ones can still be spoken.

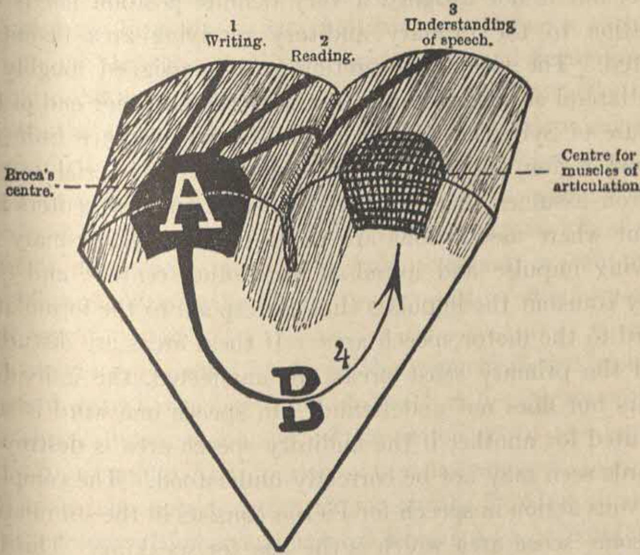


FIG. 35. — Showing connections broken in cortical and subcortical motor aphasia. In the former, 1, 2, and 3 are interrupted; in the latter only 4. (From Bing.)

The Sensory Aphasias. — The motor center for speech is stimulated to activity by auditory or visual stimuli. It has been asserted that one must either hear or see a word and repeat it or represent the word to one's self in auditory or visual terms if one is to speak. This process of representation or perception involves the action both of the primary auditory or visual centers and of a second area which Piéron asserts to accompany what we call the interpretation of the word. In the case of hearing, the region in which what Piéron calls the coördination of auditory speech is found in the temporal lobe, but is not assigned a very definite position nor is the relation to the primary auditory receiving area definitely stated. The visual interpreting area is assigned roughly to the lateral surface of the cortex near the posterior end of the fissure of Sylvius. This is a considerable distance from the visual region on the calcarine fissure of the mesial cortex. Piéron assumes that each of these coördination centers is a point where associations are made between the primary receiving impulse and impulses from other centers, and that they transmit the impulses that correspond to the formulated word to the motor speech area. If these areas are disturbed and the primary sense areas are unaffected, the individual hears but does not understand. In speech one word is substituted for another if the auditory speech area is destroyed. Words seen may not be correctly understood. The complete nervous action in speech for Piéron consists in the stimulation of some sense area which is the cue for speaking. This impulse proceeds to the coördination area where it is connected with other sense areas, and from these it proceeds to the motor speech center. Here it arouses new impulses which are distributed in proper proportion and with proper timing to the motor areas. These arouse directly the muscles of the chest and abdomen, and of larynx and mouth that produce the sound.

Head's Theory of Aphasia. — A slightly different interpretation is given of the war cases that were studied by Head. Head's belief in general is that the simpler connections are made in the thalamus just as Lashley asserted that discrimination of brightness was thalamic. The function of the cortex is restricted to wider interpretations of meaning. Meaning is the accompaniment of widespread reactions of the cortex rather than of specific centers. Still Head does recognize four kinds of aphasia each connected with lesions of definite regions of the brain. There is a close similarity between the disorders he ascribes to a given region and those assigned by Piéron, so that the difference between them is in general theory rather than in fact. Head recognizes a verbal aphasia in which the patient cannot accurately pronounce the words although he may know them when he hears them or can pick them out on a card. He may be restricted to *yes* or *no*. In slighter injuries he may merely slur difficult words as saying *tenical* terms for *technical*. Head found this type of defect associated with bullet wounds in the third frontal convolution, the Broca center, and in the Island of Reil near it.

A second type, called by Head the *syntactical*, was marked by great disturbance of rhythm of speech and by grammatical mistakes. Words came with little reference to the proper order or meaning. The patient could understand what was said to him but could not speak for himself any but the simplest phrases. Syntactical aphasia occurred in patients with injuries to the temporal lobe. Nominal aphasia was marked by inability to use names. The patient could not name colors or common objects. The words at his command were well pronounced and the intonation was normal, but a word desired could not be found. He might try various combinations of sounds more or less like the word he desired. Defects of this kind were shown by patients wounded in the angular gyrus, a convolution at the end of the first fissure below the fissure of Sylvius.

The fourth type was called *semantic* aphasia since it was characterized by difficulty in appreciating meanings. Patients with this form of disease lose the capacity for appreciating the total meaning or end of any act although they may seem to appreciate the details. A patient with semantic aphasia may read aloud perfectly but be unable to understand what the words mean and may feel that they do not make sense. He also has difficulty in making change and in performing any task which involves working towards an end. The wound in cases of semantic aphasia is found in the supramarginal gyrus that curves about the end of the fissure of Sylvius.

It is striking that the areas ascribed to the different kinds of aphasia are approximately the same for Head and Piéron. The Broca area or third frontal convolution for both is assigned to the function of uttering the words. The difference is that Piéron regards this as a distributing and coördinating center for motor impulses, while for Head it is also a region which is connected with internal speech and gives rise when injured to disturbances of writing as well as of speech. The upper part or first convolution of the temporal lobe is for both a region whose injury produces a disorder of speech. Piéron regards it as the region where words heard are interpreted, Head thinks of it as the area which makes possible putting together the separate words. When this area is injured, Head finds the patient cannot put words together properly and is likely to talk in jargon. Both also assign definite functions to the region bordering the parietal and occipital lobes. Piéron has but one region, the angular gyrus, to which he assigns the function of interpreting seen words. Head has two different regions, the angular gyrus which makes possible understanding words and naming objects and colors, and the area just above which is connected with understanding in general. Head gives to both a more complex and less specific function than does Piéron. It is striking that the same areas should be chosen for the language functions, and that the task of each should be so similar, in spite of the general differences in theory between them. The two theories illustrate the rival general attitudes towards brain function, and it is still too early to say which will ultimately receive general acceptance, or how they shall be compromised in the final theory if one is agreed upon.

The Left Brain Dominates. — A fact of importance is that one hemisphere tends to dominate the other. In right-handed individuals, for example, the speech functions are connected with the left cerebrum alone. If the right brain be injured in the Broca area or other critical areas for speech, no disturbance occurs. In the left-handed individuals who

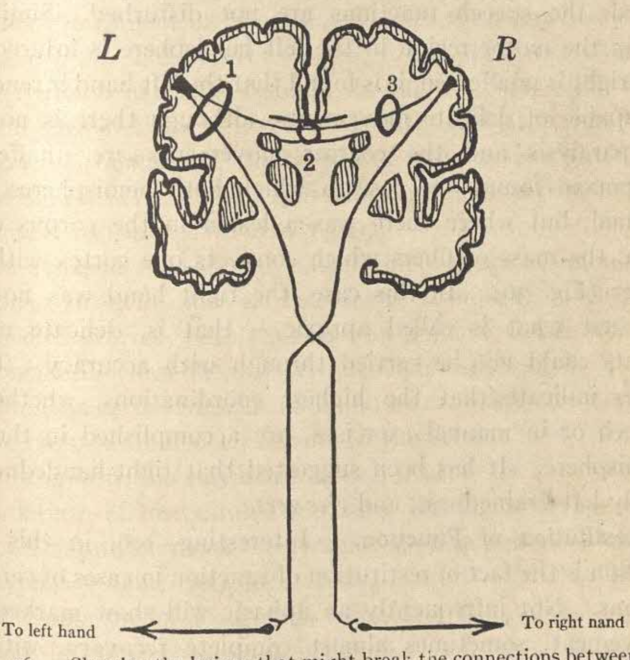


FIG. 36. — Showing the lesions that might break the connections between the left and right hemispheres and so produce apraxia of the left hand. If the lesion is at 1, the right hand will be paralyzed as well; if at 2 or 3 only apraxia of the left hand is caused. (From Bing.)

have shown symptoms of aphasia, the lesions were on the corresponding areas in the right cortex.

Apparently this is only one phase of the general fact that in right-handed individuals the left hemisphere cares for the more important and delicate coördinations, while, with exceptions, the right hemisphere dominates in the left-handed individuals. If the right hemisphere be injured in the third frontal convolution but the primary motor centers be not injured, the speech functions are not disturbed. Similarly, when the motor region in the left hemisphere is injured but the right is unaffected, it is found that the left hand is rendered incapable of delicate movements, although there is no sign of paralysis and the coarser movements are unaffected. Liepmann found one case in which both hemispheres were normal, but where there was a lesion in the corpus callosum, the mass of fibers which connects one cortex with the other (Fig. 36). In this case, the right hand was normal, the left what is called apraxic, — that is, delicate movements could not be carried through with accuracy. These cases indicate that the highest coördinations, whether in speech or in manual exercises, are accomplished in the left hemisphere. It has been suggested that right-handedness is really left-brainedness, and *vice versa*.

Restitution of Function. — Interesting, too, in this connection is the fact of restitution of function in cases of cerebral lesions. Not infrequently an aphasic will show marked improvement, sometimes almost complete recovery, with no betterment of the lesion. In surgical cases the patient will frequently show considerable paralysis immediately after part of the cortex has been removed, but with the passage of time his movements will become normal again. Franz and Oden removed the cortical area for the control of the right arm in a monkey and then compelled him to use that arm by binding the left so that it could not be used and also gave manipulative treatment that forced its use. After only three weeks of this treatment the initial complete paralysis had disappeared and the arm was used as well as ever. How the functions are restored is still an open question. It is possible that the cortical control is replaced by the action of the thalamus or other lower centers. It has been suggested that the opposite side of the brain may take over the function, although Franz eliminated that explanation by removing the area for the control of the left arm after the right had been operated upon and recovered. He found that the left arm recovered also about as quickly as did the right, and both cortical areas for the control of the arm had then been destroyed. If one accept the theory of mass action, the facts would offer relatively slight difficulty, for one part does as well as another in the control of any part.

The Synapse. — An important problem in the action of the nervous system is how an impulse is transferred from one neurone to another. There is no continuity of tissue between neurones and consequently the principles that apply to the transmission of the impulse along an axone cannot be applied to the passage from one element to the other. The point of transfer is from the end brush of one neurone to the dendrite of the other. This point of contact is known as the synapse. How an impulse crosses the synapse is an important problem in psychology and neurology, because much of the action of the nervous system is assumed to be determined by it. The synapse in many theories is believed to influence the course of all impulses through the nervous system. It is said to determine the particular reflex that shall respond on stimulation and is the point at which the changes involved in learning, either motor or sensory, occur. It determines the direction of impulses, since apparently an impulse could spread in all directions within the neurone but crosses the synapse only in the direction from end brush to dendrite. Since the dendrites are the only receiving points, this decides the direction that an impulse shall take through the neurone.

The essential points in any explanation of the synapse are: (1) Is what crosses the synapse electrical or chemical in nature? (2) How does the synapse offer resistance to the passage? (3) How does the resistance decrease with repeated action? The nerve impulse is both electrical and chemical; the question is, which crosses the synapse? That the synapse offers resistance is evident from the fact that more time is required to cross the synapse than to travel the same distance within the neurone itself. The evidence for diminution of resistance with use is that actions become easier when repeated, and the assumption is that this is due to reduction of the resistance at the synapse. Not all of the theories explain each of these points. Each emphasizes one aspect more strongly than the others. Theories group themselves into three classes. The first emphasizes the membrane of the neurone as the effective obstacle and assumes that transmission is by osmosis. The second assumes that response of one neurone to the other is dependent upon electric tuning. The third emphasizes the

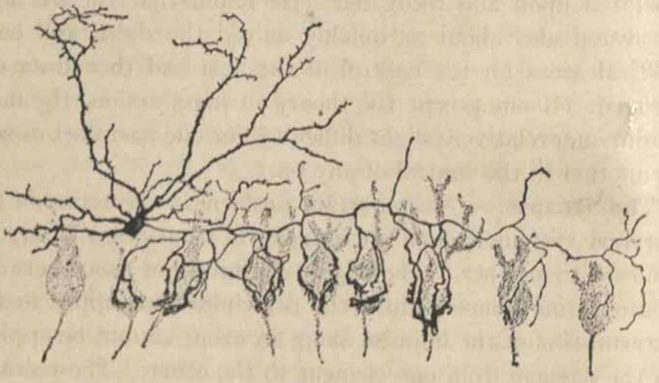


FIG. 37. — The numerous points of connection of a neurone from the cerebellum of a rat. (Cajal.)

possibility of physical movement of the processes of the neurone that may bring them into physical contact.

Synaptic Resistance Due to a Membrane. — Sherrington is the most prominent representative of the membrane osmosis theory. He demonstrated the various facts concerning the reflex which make it probable that the synapse is the critical point in the reflex path. He then assumed that the cell of the neurone, like any living cell, is a fluid enclosed by the membranes of the wall of the cell. Through this cell the chemical processes that constitute the impulse must pass. The wall permits passage in one direction only, and it makes passage more difficult than along the same distance of the axone. This resistance is reduced by each passage of the impulse across the synapse, although how this reduction is brought about is not definitely asserted.

Chronaxie. — A truly electrical theory is suggested by Lapicque in his chronaxie theory. Lapicque demonstrated that each sense organ requires a minimum time for its excitation. He also showed that there is an electric rhythm in each nerve and each muscle, and these must be the same in rate if one is to excite the other. This was confirmed by his proof that the effect of the South American Indian arrow poison, curare, in paralyzing its victims was due to its effect of changing the rate of the electric oscillation of a nerve so that it no longer corresponded to that of the muscle. The theory has been transferred to explain the influencing of one neurone by another as by Dr. Douglas. He assumes that one neurone could influence another only if they were tuned to the same frequency. The resonance resembles closely the selection of a radio station by suitable tuning. As applied to the passage of impulses from neurone to neurone, several supplementary hypotheses need to be made. For reflex paths that are not changed by use the theory would work very well. How tuning of the elements could be modified by use so that neurones which did not at first transmit from one to the other would act in common after they had been excited together is not explained. It would also need to be assumed that the electrical oscillation, the period of whose alternation determines this transfer, is different from the current that accompanies the nerve impulse. That varies with the intensity of the stimulation. The chronaxie is constant for the same neurones. The action current is also much slower in its oscillations than the chronaxie waves. The current of action oscillates from 5 to 150 times per second, while the rate of oscillation involved in chronaxie is much more rapid, from 125 to 1000 times per second. The theory is suggestive at the present stage and is probably capable of farther development.

A third theory has been suggested in different details but with essentially the same principle by Kappers, Child, and Coghill. Fundamentally all three assume that neurones which are active at the same time tend to extend their processes towards other active neurones. Kappers states that processes grow towards a cathode or negative pole (neurobiotaxis) and that all protoplasmic activity is accompanied by negative charges. Coghill has shown that in the developing amblystoma axones of neurones grow towards the active parts of the embryo. Child showed that the most active parts of a developing organism tend to draw processes from developing neurones and even the cell bodies themselves towards them. This general law has been modified to assert that the small branches of end brushes and dendrites of fully developed neurones retain this characteristic and may extend, under the influence of the activity of a neighboring neurone, so that the small gap that usually exists at the synapse is bridged. The contact that results would make possible the transmission from one element to another of either the electric or the chemical changes involved in the nerve impulse. It incorporates a number of highly important facts in a suggestive theory.

More generally it gives a theory of learning applicable to the organismic theory which would neglect the detailed action of the elements.

All of the theories have points in common and need not be mutually exclusive. All accept as facts the transmission from point to point in the nervous system, that this transmission is first within the neurone, and that the impulse passes from one neurone to another at the synapse. All agree, too, that one neurone makes connection at different synapses with several other neurones, and that something in the characteristics of the different synapses determines which way the impulse shall go and so the response that shall be made to any stimulus. It is also accepted that the passage of the impulse across a synapse is facilitated by the passage of previous impulses across that synapse. The theories are ways of bringing these facts into connection with other known facts of nerve action. It still remains to harmonize all the facts.

The Neuronic and Organismic Theories of Brain Action. — The general theories of the action of the nervous system tend now to divide into two groups. One seeks an explanation in the action of one neurone upon another and the development of open paths between them, the other speaks in more general terms of the action of masses of nerve tissue upon other masses of nerve tissue without attempting more detailed explanations. The first picture of the action of the cortex, as of the cord, is that all is determined by the openness of paths, by the synapses. The passage of the impulse from sense organ to muscle is, as has been emphasized repeatedly, the explanation of all function, whether in cord or in cerebrum. The difference between the two is that there are more open paths in the latter over which any impulse may pass and that for the most part these paths have been opened by use, by the earlier activities of the organism. It should also be emphasized that many different stimuli coöperate in producing the activities that result from the action of the cortex, many more than act together in any of the lower centers or organs. The coöperation is made possible by the fact that many of the paths have common parts; in fact, that the motor part of the path is common to very many different acts. In the majority of cases the same muscles, and even the same groups of muscles, are used. The excitation of the motor path may be aroused by a number of sensory impressions, and the various impressions may be thought of as coöperating in the final action. What is even more important in this connection is that each sensory impression may be connected with several motor or intermediate neurones, and the action which results when the sensory impression is received must depend upon the openness of the various synapses, of paths leading to the possible motor organs that may be excited. Where very large numbers of stimuli are presenting themselves at every moment, there must be a large amount of coördination, of reciprocal influence, to determine which of the possible movements is actually made. The strongest impression and the one whose neurone has the most open synapses between it and the motor neurones will determine the action.

The Facilitation of Impulses. — In addition to the mere passage of impulses from neurone to neurone over the most open path, there is evidence of a wider control. Sherrington has explained this control as an expression of the action of one neurone or group of neurones exerted upon another to change the openness of the synapse of the second pair. Two ways in which one group of neurones may influence the action of another have been recognized. The first, the more direct, is a process of making easier the path across one group of synapses by the action at the same time of another group of neurones. This is known as facilitation. It is very commonly present. It may be illustrated very easily by the knee-jerk. You are familiar with the fact that if you strike sharply the tendon below the knee-cap when one leg is crossed over the other, the foot will give a kick. It has been shown that the kick will be much stronger if the hands are clenched at the time the blow is given. The clenching of itself would not produce the kick, but it prepares the way for, or facilitates, the response when the blow is given. This may be pictured as a preparatory reduction of the resistance of the synapse which makes the impulse pass more easily, and hence with greater intensity, when the suitable stimulus is applied.

Inhibition of Impulses. — More striking is the second form of interaction, inhibition. Certain paths when active prevent the action of others, or reduce their liability to response. Sherrington has demonstrated this phenomenon in the case of many reflexes, such, for example, as the general reduction of the strength of the reflexes of the cord when it is in connection with the cerebrum. After the cerebrum has been removed and the animal has recovered from the shock of the operation, all reflexes are exaggerated, a fact explained on the assumption that in the normal animal all lower reflexes are inhibited by the higher centers. More interesting for our immediate purpose is the fact, fully established by Sherrington and Hering, that the flexor and extensor centers in the cortex mutually inhibit each other. They removed the flexor muscles of a leg, placed the animal in such a position that there was a tendency for flexion, — it was supported only by the extensor muscles, — and noted that the member was lowered when the flexor center was stimulated. This they explained as an inhibition of the cortical center of the extensor muscle from the flexor center which reduced the tonus of the extensor, and so permitted the member to be flexed. This was also demonstrated on the antagonistic eye-muscles. If the internal rectus muscle of the eye were severed and the cortical center for that muscle were stimulated, the eye would turn as it does upon stimulation of that center when the muscle is intact. This mutual checking of antagonistic movements prevents any possibility of interference between groups of muscles in voluntary action. It makes it impossible that one group of muscles should pull against another. Inhibition is assumed by Sherrington to be due to the action of one set of neurones upon a synapse somewhere along the other path of discharge. The activity of that set of neurones, in some way as yet unknown, makes the membrane at the synapse much less permeable, and so prevents the discharge of the impulse across it.

These processes of facilitation and inhibition are quite as essential to the interaction of various stimuli in the cortex as in the lower centers. As will be seen from time to time in considering the mental processes, the most important and striking fact is the wide interaction of mental processes. It is seldom that an act or a thought is controlled by a single stimulus alone or even by the stimuli that are being received at the moment of action. The laws of facilitation and inhibition of one set of cortical activities by others that are going on simultaneously in other paths and in other areas, are needed if we are to obtain any accurate picture of cortical action. We shall have occasion to return to these interactions in our explanations of mental processes.

THE AUTONOMIC NERVOUS SYSTEM

The Structure of the Autonomic System. — In addition to the central or cerebro-spinal nervous system with which we have been dealing so far, the psychologist must also know something of the autonomic nervous system. Its function is to excite movements of the viscera, of the pupil, evoke secretions of the glands and control other vital functions which are not at all under conscious control. The autonomic system is generally divided from its function into three parts: the cranial autonomic, whose ganglia are in the head and neck; the sympathetic or thoraco-lumbar division; and the sacral division. The autonomic system consists of isolated masses of cell-bodies, the ganglia. The ganglia of the cranial divisions are irregularly arranged. One is in the eye-socket back of the eye-ball. The sympathetic ganglia are for the most part arranged in pairs in the ventral cavity in front of the spinal column. The sacral ganglia are near the organs controlled. All receive fibers from the cord and from spinal nerves which connect with their cell bodies. From their cell bodies non-medullated fibers extend to the muscles and glands which they excite.

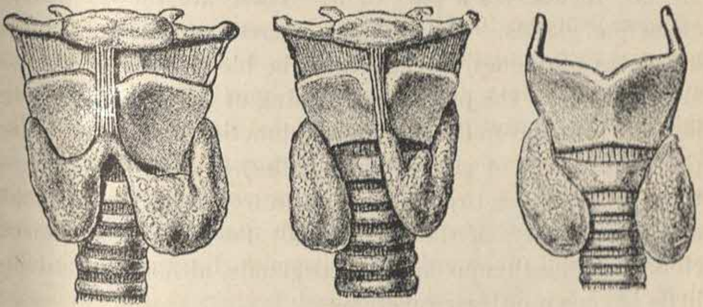


FIG. 38. — Shows different types of thyroid glands and the relation to the trachea in the center. (From Luciani's "Human Physiology.")

The nerve impulses travel very slowly along these autonomic fibers as compared with the impulses within the central nervous system, and the unstriped muscles which they supply also contract more slowly than the striped muscles of the limbs and trunk. The responses of these vital organs are consequently all delayed relatively. The impulses from the autonomic system extend to all parts of the body. They cause changes in the size of the blood vessels, erection of the hairs in animals, changes in the size of the pupil, peristalsis of the alimentary canal, and secretions of all glands. They regulate all of the purely vital activities. They affect consciousness mostly by their activity during emotion, and we shall consider their action more in detail in that connection.

THE ENDOCRINE GLANDS AND THE ACTIVITY OF THE NERVOUS SYSTEM

The Ductless Glands. — We may mention here briefly a series of relatively recently discovered organs which have an important influence upon the nervous system although they are not themselves a part of it. These are the ductless or endocrine glands. These glands secrete certain substances, known as hormones, directly into the blood. The hormones are essential to the proper functioning of the nervous system in particular and to the growth and functioning of many other parts. The list of glands which influence the nervous functions includes the thyroid and pituitary, the adrenal glands and certain parts of the sex glands. Possibly we should include also the thymus and pineal glands, although relatively little is known of their functions.

The Thyroid Glands. — The best known are the thyroid glands, relatively large masses in the front part of the throat (which, when abnormally enlarged, produce goiters). The secretions of the thyroid are essential to the mental life and to the proper growth of the brain. A cretin, who is an individual with defective thyroid secretion, is of the mental level of a child of four or five, is short in stature, with general infantile contours of the body. That this is due altogether to lack of thyroid secretion is shown by the fact that feeding a developing child thyroid extract from a sheep induces a marked growth and increase in intelligence. A marked cretin at two years may be a normal child at three. The treatment must be begun early if it is to be effective, and the improvement will continue only so long as the treatment is kept up. Excess of thyroid secretion, on the other hand, induces an abnormal excitability, particularly of the emotions. Hyperthyroidism is marked by excessive pulse rate, by wasting, and muscular weakness, and by great irritability.

The Pituitary Body. — The pituitary body is a small protuberance on the under surface of the brain stem, just back of the optic chiasma, or crossing of the optic nerve. It is connected with the third ventricle by a hollow tube. Three parts can be distinguished, with secretions differing in function. The anterior portion secretes a substance that promotes the growth of the body, particularly of the bones and connective tissues. Cases of giantism, associated with mental disturbances, have been traced to excessive secretions of this anterior lobe. The intermediate portion secretes a substance which increases the contraction of unstriped muscles, and another substance which probably passes directly into the ventricles of the brain and is essential to the proper functioning of the cortical tissues. Disturbances of this secretion result in a marked decrease in intelligence. The function of the posterior portion is not known.

The Adrenal Glands. — The adrenal glands are small glands near the kidneys, which have connections with the sympathetic nervous system. Excitation of the fibers innervating these glands induces a secretion directly into the blood that increases the heart rate, changes the composition of the blood, and causes the flow of glycogen from the liver. This adrenal secretion is an important factor in emotional excitement, and we may postpone details until we consider them in that connection.

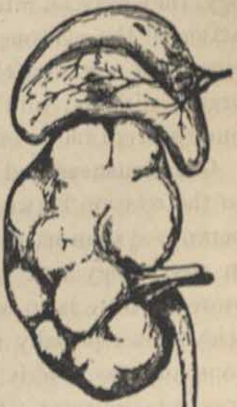


FIG. 39. — The adrenal gland and the kidney. *r*, kidney; *s*, adrenal gland.

The Gonads. — Parts of the ovary and testis also secrete hormones which affect the nervous system. These secretions are essential to the proper growth of the primary and secondary sex organs. They also contribute to the development of the more nervous or mental traits that constitute in sum the feminine or masculine character of the individual.

Other Glands. — It has been suggested that the pineal gland may have a similar function, possibly to inhibit the effects of the pituitary secretion, but the evidence is contradictory, and we must await further evidence before we can include it among the endocrine glands. The same may be said of the thymus.

The ductless glands as a whole are important because they secrete substances which are essential to the growth of the nervous system and to its proper functioning. For psychology, they have an interest since their action is involved in the action of the nervous system, and more particularly since in emotional reactions they influence the responses of the vital organs directly, and indirectly they render the individual more susceptible to emotional reactions.

Consciousness and the Cortex. — The general question as to the relation between consciousness and the activity of the nervous system naturally arises and has been much discussed in psychology and philosophy. It takes two forms. The more concrete is to what parts of the nervous system is consciousness especially related. The more general is how does consciousness modify the body, or the nervous system influence consciousness. Consciousness obviously does not accompany all activity of a nervous type. Many of the lower parts of the brain are active during sleep while we are not conscious. Consciousness accompanies activity of the cortex of the cerebrum. Even in the cortex many parts must be active when we are not conscious of them. Except in cases so unusual that they are regarded as pathological, there is only one consciousness as the result of the activity of the nervous system. On the basis of general evidence this may be regarded as connected with an organization of the parts of the cortex of the left hemisphere. It would be highly dogmatic to set limits for this organization within this hemisphere. The suggestion has frequently been made that it may be connected with the frontal lobe. Just as good a suggestion would assign it to the entire central region including the visual portion of the occipital lobe, the upper temporal and posterior portions of the frontal lobe. The dominance of the left hemisphere for speech and motor control suggests the left hemisphere for right-handed individuals. The central region is suggested because injuries within it have fairly definite effects. Lashley's results would indicate that any injury has an influence. There is no reason for excluding any part of the cortex from contributing to consciousness. The importance of a single organization to which widely spread masses of structures contribute needs to be emphasized. The limits must be left indefinite.

The Relation of Body and Mind

Much discussed from the time of Descartes has been the question as to how mind or consciousness is related to the nervous functions or processes. The difficulty with obtaining an idea of the nature of the relation is that no possibility exists of experiencing a conscious process and the corresponding nerve process at the same time. The brain of a patient has been exposed for an operation and a delicate electrical recording apparatus attached to the visual area in the occipital lobe. It has been shown that when the patient sees a light, an electrical current develops in a restricted area on the calcarine fissure. The patient sees the light; the experimenter has evidence of the electrical activity. The patient is not able to appreciate the current or the nerve changes which accompany it. The experimenter cannot become aware of the image of the light in the patient's consciousness. The two are undoubtedly separate phases of the same process. How they are connected is the problem.

Probably little is to be gained by enumerating the different theories that have been suggested in the attempt to explain how the two are related. Most of them make assumptions that are not in harmony with observed facts or modern theories of mind or body. Any explanation must also attempt to apply the notion of cause that has developed to explain physical interaction in a field for which it is perhaps less suitable. We may content ourselves with the statement that the sensation of the light and the changes in the neurones in the cortex that give rise to the electric discharge are certainly related most intimately. Possibly the best formulation we can make at present is that they are both phases or ways of becoming aware of some unitary activity or reality. At present we have no good analogy for explaining the connection and no satisfactory theory as to what the common reality may be.

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CHAPTER IV

SENSATION

General

The initiation of all responses, from the reflex to the most definitely intended or voluntary acts, and the primary qualities of all knowledge are dependent upon stimulations of the sense organs. The discussion of the nervous system showed clearly that all motor neurones are stimulated by sensory impulses and that the sensory neurones all receive their original excitation from the sense organs. On the other hand all the qualities of objects as we know them are derived originally from the sense organs. It may be assumed that the characteristics of an object directly perceived is due to or at least transmitted by the sense organ. It is a matter of direct observation that the remembered and imagined objects have the same qualities as sensations and exhibit only those qualities that are present in sense. One cannot picture to one's self what color an ultra-violet or infra-red ray would have if one should by some chance develop an organ that would be sensitive to them. Memory, imagination, and reasoning involve only the characteristics of objects that are presented by sense. They may recombine them, they may make use of the sense qualities in new ways, but they can add no new qualities.

Qualities Depend upon the Sense Organ. — It is conceivable that the qualities of sensation might depend either upon the nature of the stimulus or upon the nature of the sense organ that receives the stimulus. The popular mind assumes that the qualities we perceive are the qualities of the external stimulus, that colors actually belong to objects, but the facts of physiology indicate that the nature of the sensation depends quite as much upon the sensory tissue that receives the impression, as upon the stimulus itself. Thus we see that different stimuli acting upon the same sense nerve always give rise to the same sensation. Menthol, pressure, a deviation above or below a temperature of 30° centigrade, or a slight electric current all produce the sensation of cold when they are applied to a cold spot. On the other hand, the same stimulus applied to different kinds of sensory tissue always gives rise to a different sensation. Pass a very mild electric current through the eye, you seem to see a color, through the tongue and you have a taste, through a pain spot, and you feel pain. These facts and others show fairly conclusively that the character of the sensation is determined by the receiving organ rather than by the stimulus. This statement is modified only by the fact that certain kinds of stimuli alone are capable of stimulating a sense organ most completely. These are sometimes called the adequate stimuli, as opposed to those that evoke a less complete response.

The Classification of Sensations. — If this principle of the dependence of sense qualities upon the nature of the organ stimulated be accepted provisionally, it furnishes a convenient means of classifying sensations. Could one but determine the different sorts of sense ends that come to the surface of the body or are imbedded in its substance, one would also have a complete list of the possible sensations. In practice one usually discriminates the sense quality first and later discovers the sense organ, but the classification nevertheless is assumed to be in terms of the sense organ. We may accept for the moment the general principle that the number of sense qualities is determined by the number of different sense tissues that are capable of stimulation. Since we can know that sense endings are different only from their responses, and have no means of telling from the appearance of a sensory end what response it will give, the problem of classification is advanced but not solved. In practice, we group the sensations according to the larger organs that receive them. Usually the organ is stimulated by a single form of energy. Thus the eye contains many nerve ends all stimulated by the light waves and gives rise to sense qualities that are in general alike. In the skin, on the other hand, four kinds of sense ends are scattered indifferently over the surface, and while we commonly speak of the skin as the sense organ of touch, there are really at least four different kinds of sensation received from the skin. Taste and smell offer an inconsistency of the opposite sort. The organs are distinct, but the stimuli are closely similar and the qualities of sensation are not discriminated by the popular mind, yet science and common sense follow the organ rather than the quality in making them distinct sense departments. One may say, then, that in classifying sense qualities, the organ provides the first means of grouping, and within the organ the subdivisions may be either in terms of the classes of stimuli, or of the qualities of sensation, or of both.

Sherrington's Classification. — A more general grouping of sense organs has been widely used since Sherrington suggested that the origin of the stimuli provided a convenient basis of division. Stimuli may originate in the outside world, in the tissues of the body itself and from the linings of internal cavities of the body. Organs which receive their stimulation from outside are called the exteroceptors. They include the traditional five senses of man. Those which are stimulated by movements within the tissues of the body are the proprioceptors. They are the sense organs in the muscles, the kinæsthetic organs, and the semicircular canals in the ears. The sense organs on the linings of the alimentary canal are most important in the third class. They are the interoceptors. Hunger and thirst are the best known representatives of this group.

Attributes of Sensation. — When one attempts to enumerate all possible sorts of mental qualities or sensations, one sees very quickly that there are various kinds of differences that are not on exactly the same level. It is not possible to arrange all the different kinds of sensation from any organ in a single series, the members of which differ from each other in one respect only. Thus in the case of sound, we may distinguish differences of pitch and also differences of loudness. These vary independently. A high tone may be either loud or faint. These different ways in which sensations may vary are called the attributes of sensation. How many attributes there are is by no means a matter of agreement. Most agree that one must distinguish differences in *quality* from the differences in *intensity*. The quality may be said to depend roughly upon the specific character of the sense organ stimulated, while the intensity depends upon the degree to which the organ is stimulated. There are exceptions to both of these statements. In the case of light, for example, the strength of stimulus in part determines what organ shall be stimulated. As will be seen faint lights stimulate the rods alone, while strong lights stimulate the cones. For vision, too, we do not ordinarily think of the changes due to differences in the intensity of the light as being of a different kind from those due to changes in the kind of stimulus, to changes in the wave length of light. Black, gray, and white correspond to changes in the intensity of the wave lengths, but the untrained observer thinks of them as just as truly colors as red or yellow. This confusion between quality and intensity is also seen in a certain degree in the appreciation of temperatures. For most of the other senses the distinction between quality and intensity offers little difficulty. Most psychologists find it convenient to recognize the distinction between quality and intensity.

Extent and Duration. — More difficult it is, however, to dispose of some of the other attributes sometimes ascribed to sensations. Thus every object possesses extent, and every event occupies time, has duration. Many authorities speak of extent and duration as attributes of sensation, as fundamental ways in which sensations may vary. In the simplest cases, these ways of varying seem immediate and unanalyzable, but in many more instances it is possible to show that the appreciation both of extent and of duration depends upon more complicated mental operations. They seem to belong to the object rather than to the sensations as such. In consequence it is more convenient to treat them both in connection with perception, as a way of interpreting objects, than to consider them as attributes of sensation.

VISION

The Stimuli for Vision. — We shall begin with the most important, if also one of the most complicated of the senses, — *vision*. The physical stimuli for sight are light waves. We appreciate waves that range in length from approximately 400 to 800 $\mu\mu$ in length.[1] Helmholtz, under favorable circumstances, saw rays as long as 835 λ and as short as 318 λ. For the average eye under normal conditions the values range from 760 λ to 397 λ. Between these limits lies the visible spectrum from red to violet. We make relatively little use of the wave lengths of light in our descriptions of colors. The qualities of colors are seldom defined with reference to the wave lengths, since none of the observed laws have a close correspondence to changes in these lengths. Thus while for tones an octave is always twice the vibration rate of the fundamental, no regular ratio exists between the colors that have peculiar relations. A color that contrasts does not have a vibration twice as rapid as the primary. A color does not have half the vibration rate of its after-image. We must turn from the physical to the physiological for an explanation of the phenomena of vision. To this end, we shall consider first the more important features of the structure of the eye.

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[1] $\mu\mu$ means thousandths of a thousandth of a millimeter. This is usually expressed as λ.

THE STRUCTURE OF THE EYE

The Mounting of the Eye. — Embryologically the eye is a part of the brain that has grown out and down to the surface of the body. It has increased the sensitiveness to light that is inherent in all tissue by the addition of photochemical substances. It has acquired a system of lenses by which definite images may be cast upon this sensitive surface, has grown protective coats, and gained a mounting that permits of ready turning in any direction. The eyes are mounted in deep conical sockets in the skull, where they are well protected. The eyeball is kept in its place in the socket by the capsule of Tenon, a pouch-shaped membrane that surrounds the posterior three fourths of the eyeball. Between the capsule of Tenon and the eyeball is the so-called synovial fluid which acts as a lubricant when the eyeball turns. The muscles in its tissue also contract with the ocular muscles and prevent them from drawing the eye back into the socket. To prevent foreign particles from entering the socket, the front is closed by the conjunctiva, a membrane continuous with the inner lining of the eyelids and the outer surface of the eyeball. The padding of fat, the conjunctiva, and the capsule of Tenon, hold the center of the eye fairly well fixed, and at the same time permit it to turn easily about that center.

The Three Coats of the Eye. — The eyeball is approximately a sphere, a little less than an inch in diameter (23–24 mm.). The spherical shape is given it by the outer or sclerotic coat, which is kept distended by the fluids within, submitted to constant pressure by the general circulation. This pressure amounts to about 25 mm. of mercury in the normal individual as compared with a blood pressure of 80 to 140 mm. The eyeball has three principal coats. The outermost, the *sclerotic* is a tough protective coat of connective tissue. Inside the sclerotic is the *choroid* coat, made up mostly of blood

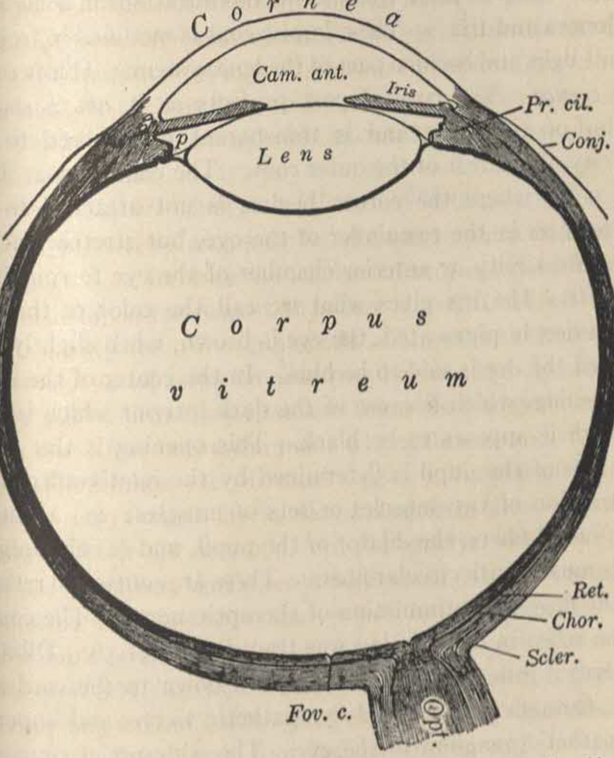

FIG. 40. — Section of the eye. *Scler.*, sclerotic coat; *Chor.*, choroid; *Ret.*, retina; *Opt.*, optic nerve; *Fov. c.*, fovea; *Pr. cil.*, the ciliary muscle or ciliary process; *Conj.*, conjunctiva; *Cam. ant.*, the anterior chamber; *Corpus vitreum*, the vitreous humor that fills the main body of the eye. (From Angell's "Psychology.")

vessels with some muscles and nerve fibers. Still farther within is the *retina*, the nervous structure and true sense organ. Each of these coats shows modifications in some part.

Cornea and Iris. — The sclerotic coat is modified in front to admit light and become part of the lens system. This is called the *cornea*. The corneal part projects as it has a shorter radius of curvature and is transparent as opposed to the opacity of the rest of the outer coat. The choroid coat, from the point where the cornea begins, is not attached to the sclerotic as in the remainder of the eye, but stretches across the front cavity or anterior chamber of the eye to constitute the *iris*. The iris gives what we call the color of the eye. When deeply pigmented, the eye is brown, when slightly pigmented the eye is said to be blue. In the center of the iris is an opening, which because of the dark interior which is seen through it appears to be black. This opening is the *pupil*. The size of the pupil is determined by the relative degree of contraction of two muscles or sets of muscles: (1) a muscle with radial fibers, the dilator of the pupil, and (2) the sphincter, a muscle with circular fibers. These are controlled reflexly by the degree of stimulation of the optic nerve. The course of the reflex in constriction was traced on page 56. Dilation involves a reflex through a long path down to the cord and back through the cervical sympathetic nerve and superior sympathetic ganglion to the eye. The widespread course of the pupillary reflex makes it very important in the diagnosis of nervous diseases in general. It is affected by lesions in many different structures. In the normal individual, the constriction takes place promptly on increase of illumination, while dilation is relatively slow because of the long course through the sympathetic nerves. The constriction of the pupil is largely protective by reducing strong lights, but also has somewhat the effect of the diaphragm of a camera. It gives better definition because it 'stops down' the pupil when the light is strong enough to permit and, when the light is faint, it admits more. Constriction of the pupil also accompanies accommodation to near objects.

The Eye as an Optical Instrument. — Within the eyeball are two chambers separated from each other by the lens. Just back of the cornea is the anterior chamber (*Cam. ant.*, Fig. 40), filled with a fluid that is mostly water, the aqueous humor. The iris protrudes into the back portion of the anterior chamber. Just back of the iris is the *crystalline lens*. This consists of a large number of layers, which increase in density and so in refractive index from outer layer to the center. This arrangement increases the effective refractive index of the lens. The lens is held in place by the *suspensory ligament*, a continuous circular membrane which is attached to the side of the *ciliary* muscle. The ciliary muscle, in turn, is stretched from near the point where the sclerotic coat becomes the cornea (the corneal angle) to lose itself in the choroid coat farther back. Lens and suspensory ligament together divide the anterior from the *posterior chamber*. The posterior chamber, the larger portion of the inner cavity of the eye, is filled with the *vitreous humor*, a thick jelly-like substance, named from its resemblance to molten glass. The function of the various surfaces of the media is to refract the rays of light so that an image of external objects may be projected upon the retina. For that the cornea and the lens are the most important.

The Dioptrics of the Eye. — The contribution of the different structures to the formation of the image has been carefully studied by a determination of the distances between different structures, and by determining the refractive index of the different fluids, the cornea, and the lens. The important refracting surfaces are three, the front surface of the cornea and the front and back surfaces of the lens. The indices of refraction of the cornea, and of the aqueous and vitreous humors, are approximately identical, and each is approximately the same as that of water, — 1.337. The refractive index of the lens in practical effect is 1.437. The average radius of curvature of the cornea is 7.7 mm., of the front surface of the lens is 10 mm., and of the back surface is 6 mm. Calculation of the optical efficiency of the eye from these figures gives it a value of from 60 to 66 diopters.[1] The simplest way of representing the efficiency of the lens system is to use the analogy of the pinhole camera. If one admit light to a dark box through a small opening, one obtains an image on the back of the box of bright objects in front of the hole. Rays of light pass in a straight line from each point on the bright object through the pinhole to the corresponding point of the image on the back of the box. In any lens system there is a point through which we may picture the rays of light as passing. This point we call the nodal point (*n* in Fig. 41). In the average eye, the nodal point is 15.5 mm. in front of the retina and 7.3 mm. back of the cornea. The size of the retinal image cast by objects in the outside world and other relations of light rays are sufficiently accurately

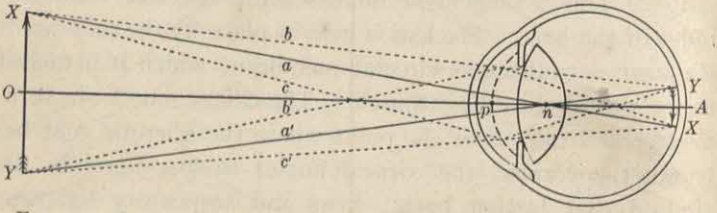

FIG. 41. — The formation of the retinal image. The diagram shows refraction of three rays of light from *X* and *Y* that focuses them on the retina, and the inversion of the object. *p* is refracting surface of reduced eye. (From Foster's "Physiology.")

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[1] A diopter is defined as the strength of a lens that will bring parallel rays to a focus at a distance of one meter. The number of diopters of a lens is determined by dividing one meter by the length of its principal focus. The nodal point of the eye is assumed to be 15.5 mm. in front of the retina. If we divide one meter (1000 mm.) by 15.5 we obtain ca. 66.5.

determined for most purposes if one assumes this position for the nodal point, and that the principal rays pass through it on the way to the retina.

The Mechanism of Accommodation. — A camera or other optical instrument that could not be focused for different distances would be of little use. Most young human eyes can be focused for objects at different distances. This focusing is accomplished by changing the shape of the lens. When the eye looks at distant objects the lens is flat, when it looks at near objects, the lens becomes thick and the radius of curvature of the front surface becomes much shorter. One can see the lens push forward the iris if one will look across the eye of a person as he observes closely a printed word held 10 inches away from the eye. As was said the lens is held in place by the suspensory ligament, a membrane which extends from both surfaces of the lens to the side of the ciliary muscle. When the eye is at rest in looking at distant objects the ciliary muscle is relaxed, and so is thin. The suspensory ligament is then stretched and holds the lens flat. When one becomes interested in a near object the ciliary muscle is reflexly contracted. This permits the lens to expand to assume its natural

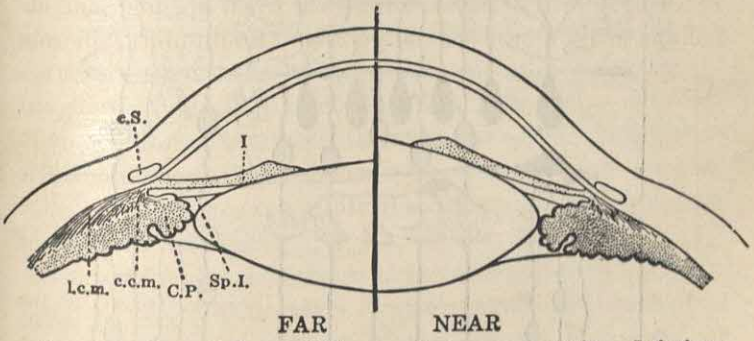

FIG. 42. — Change in lens and ciliary muscle in accommodation. Left shows accommodation for distant, right, for near objects. (From Foster's "Physiology.")

rounded form. It is thicker than when the eye is at rest and the front surface has a shorter radius of curvature. With this relaxation of the suspensory ligament, the lens drops down

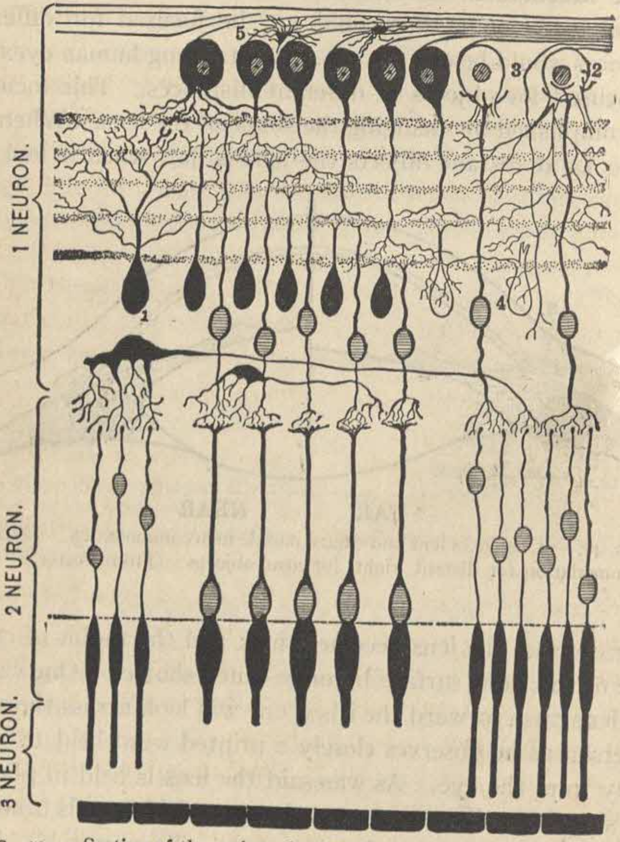

FIG. 43. — Section of the retina, showing the neurones. (After Cajal.)

a little and can be seen to be shaken as the head moves. The ciliary muscle is the only one in the body that decreases strain upon a ligament when it contracts. It is also the only one in which the ligament is attached to the side of the muscle and not at the end. Since the accommodation for near objects is dependent upon the elasticity of the lens, and as one grows older the lens becomes less and less elastic, adjustment for near objects becomes less and less with increased age. Most individuals of 45 or more can read only if they aid accommodation by the lenses of glasses.

The Structure of the Retina. — The retina is the part of the eye that is sensitive to light and receives and transmits the visual impressions. It covers the back of the eye, inside the choroid coat. It has a thickness of from 0.3 to 0.35 mm. As was said, the retina is embryologically a part of the central nervous system come to the surface of the body. It has a complicated structure as does the brain, since it is composed of three layers of neurones, the rods and cones, which receive the stimulation; the bipolar cells, and the large ganglion cells, whose axones constitute the optic nerve and carry the impulses to the brain.

The *rods* and *cones*, the structures sensitive to light, are directly in front of the layer of pigment cells and the choroid coat in the outermost part of the retina. The cones are relatively short and thick, from 4–6 μ (μ = .001 mm.) in diameter and 30–40 μ long. The rods are longer and more slender, 2–4 μ across and 40–60 μ long. They are crowded about as closely together as is possible, so that the distance from center to center of the elements is not much greater than the diameter of the single element. In both the rods and the cones can be distinguished an outer section and an inner section. Just at the base of the cones and a little distance away from the rods is a swelling that corresponds to the cell-body of the neurone. The axones of the rods and cones come into contact with the dendrites of the bipolar cells, and the axones of these in turn with the dendrites of the large ganglion cells. A cone connects with a single bipolar cell and that in turn with only one ganglion cell. Thus the impulse from each cone is kept separate all the way to the brain. Single bipolar cells make connections with more than one rod. In addition to these direct lines of connection with the central nervous system, there is a layer of cells between the rods and cones and the bipolar cells which serves to connect different rods and cones horizontally. It is possible, even probable, that some of the spreading of impulses in contrast and irradiation takes place over these horizontal cells. In addition to these nerve cells, throughout the retina are found supporting cells of non-nervous tissue, the so-called Müller cells. In the innermost layer are fibers, the axones of the ganglion cells, which unite to constitute the optic nerve and carry impulses to the cerebral nervous system.

Fovea. — Certain parts of the retina show modifications from this general arrangement that make them of particular interest. One of these, the fovea, lies about 1° to the outside of the point where the optical center of the optic system intersects the retina. It is the point of clearest vision and is reflexly turned to the point that we attend to. As its name implies, it is a pit or depression in the retina made by a drawing apart of the front coats of the retina. This pit is due to the fact that axones which lead off from the cones go towards the outside of the fovea. This brings the bipolar and ganglion cells that receive the impulses from the cones in the fovea to one side of the line of the light coming to them from the pupil. Also, there are, in the fovea, none of the blood vessels, which in other parts of the retina are found in the outer coat. The cones here are almost next to the vitreous humor, and the light need pass through little other retinal tissue before they are reached. In the fovea, too, are found only cones, and these are smaller and longer than in other portions of the retina, from 2–4 μ in diameter and 40–60 μ long, or of about the same dimensions as the rods in other portions of the retina. The cones become relatively less and less numerous, the rods more and more dominant as one proceeds from the fovea outward, and cones are not found at all at the extreme periphery. The fovea is at its deepest about 0.3–0.4 mm. in diameter. The rod-free area is a little larger, about 0.8 mm. across.

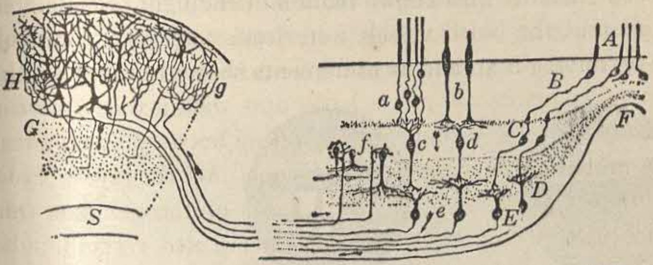

FIG. 44. — Section of the fovea. It may be seen that the axones of the cones extend toward the periphery to make connection with bipolar and ganglion cells. On the left may be seen the central cells to which the visual impulse is carried. (From Cajal.)

Yellow Spot and Blind Spot. — About the fovea for an area from 1–3 mm. in diameter the retina has a distinctly yellowish hue. This appears as a rose colored area in the center of the field of vision if, in a dark room, one will look intently through a cobalt colored glass plate at a lighted surface. Psychologists sometimes use the terms fovea and yellow spot or macula lutea interchangeably. This is only loosely permissible as the macula is much larger than the fovea. Another region that deserves special mention is the blind spot, the area at which the optic nerve leaves the eye. This contains no rods or cones, but only the fibers, axones of the large ganglion cells, which unite to form the optic nerve. It is an area about 1.5 mm. (4°–6°) in diameter, about 5 mm. (15°) to the nasal side of the fovea.

The Rods and Cones Are the Organs of Vision. — There is very good evidence that the rods and cones are the organs of vision. (1) Vision is absent where the rods and cones are lacking at the entrance of the optic nerve. (2) The shadows of the blood vessels in the outer coat of the retina may be seen under suitable conditions, and H. Müller has measured the distance of these blood vessels from the perceiving organs by a method of triangulation based on the apparent displacement of their shadows with known motion of the light outside. He found that the blood vessels were from 0.17-0.33 mm. from the perceiving coat, and measurements showed that the actual distance in the retina between blood vessels and the layers of rods and cones was from 0.2 to 0.3 mm.

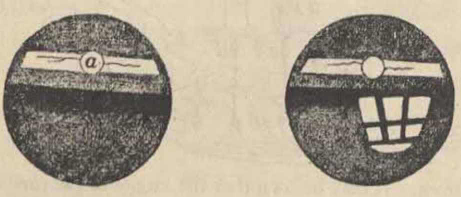

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FIG. 45. — Optogram. (1) shows the normal appearance of the rabbit's retina. (2) shows the condition when the rabbit has been permitted to look at the window of the dark room and then is killed while still in the dark and the retina fixed as a photographic negative is fixed.

The problem as to what changes go on in the retina when it is stimulated, what actually makes one see, has aroused much discussion. Two changes can be seen to take place. One is a change in the color of the pigment in the rods. The retina of a frog killed in the light has a very light color. If, however, it be killed after being kept a long time in the dark, the rods have a delicate purple hue. Pictures may be taken with the retina of a rabbit. If the rabbit looks for a little time at the window of a dark room in which it is placed, then is killed and the retina fixed as one would fix a photographic plate, a picture of the window can be seen on the retina. Such an optogram is shown in Figure 45. The second change is in the length of the rods. If one compare the cones of an animal killed after exposure to bright daylight with one killed after being kept in the dark, one will see that the former are much shorter. The cones contract when stimulated by a bright light. The rods, on the other hand, extend in the dark. A third change that can be observed is a movement of the pigment cells. These pigment cells are hexagonal in shape and are found in the dark adapted eye between the retina and the choroid coat. In an animal killed when bright adapted, the processes of the pigment cells are found between the ends of the rods. It is evident that when the eye is stimulated by light, the pigment cells move from their position at the outer surface of the retina up in between the outer ends of the rods. Both the changes in the cones and in the position of the pigment cells and in the length of the cones can be seen in Figure 46. Of these changes only the bleaching of the visual purple has been given a meaning for seeing. The visual purple seems to act as a sensitizer for the retina in faint light. It explains why one can see so much better after a long period in the dark. Experiments show that the normal eye, after being in complete darkness for an hour, appreciates a light that is only one

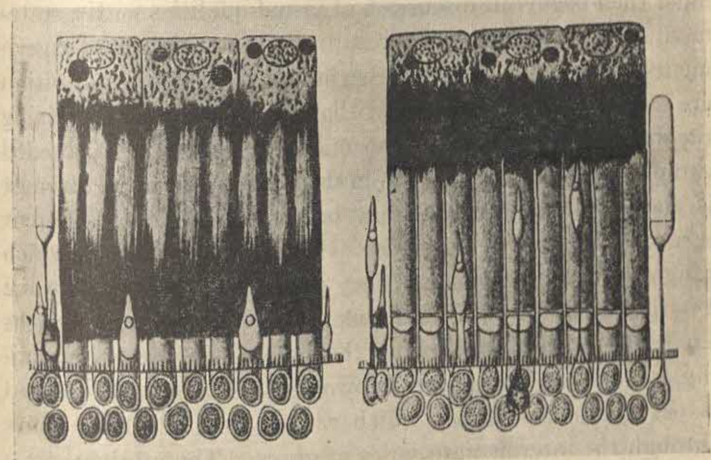

FIG. 46. — Changes in the retina with stimulation. Left is bright adapted; right, dark adapted. In the bright adapted eye the black pigment is between the rods. The cones are contracted. The rods are elongated. In the dark adapted retina, the pigment is at the outer end of the rods. The extended cones are prominent. (After van Genderen Stort.)

thousandth part as bright as that which is appreciated when the eye has been in bright daylight.

SENSATIONS OF SIGHT

The Visual Qualities. — All explanations of vision have been developed on a study of the phenomena of sight rather than upon the direct observations of changes in the eye. We must then begin our discussion of visual qualities with a statement of the more important results of observations and experiments. It should be said in beginning that theories of vision are still widely divergent and that there is danger of mixing theory with fact. Indeed no one seems to have succeeded completely in isolating fact from theory even when the attempt is made. Visual qualities may be arranged in four different series. The first is the series of pure spectral colors which ranges from red to violet. They correspond directly to wave lengths in the physical stimulus. The longest wave lengths excite the red, and the shortest the violet. The qualities ranging from red to violet are known as the hues. The second is the achromatic series which ranges from black to white through the intermediate series of grays. These brightnesses are decidedly relative, for a shade that may seem black against a very bright surface may be a light gray against a very dark surface. The grays correspond to increases in the strength of the physical stimulus. They can be obtained, however, only from a suitable combination of wave lengths, not from one alone. The third series accompanies change in the intensity of a single color or wave length. If a single wave length of red of very slight intensity affect the retina it seems black. Increase the intensity and there is a gradual change from a dark brown to a brilliant red. Continue to increase the intensity and the red becomes pinker until in theory it may change to white. The fourth series corresponds to the mixture of a single wave length with grays of the same intensity. The sensations that result range from the pure color to a gray. The amount of the admixture determines what is called the degree of saturation of the color. The pure color is saturated, and the greater the amount of gray, the less the saturation. The last two variations are frequently mixed; saturation and brightness often change together.

The Color Pyramid. — The four series have been represented schematically by a double pyramid (Fig. 47). The pyramid is used by the supporters of one theory and assumes that there are four colors from which all of the others are compounded. Another widely held theory assumes that there are but three primary colors and would use a double tetrahedron for its model. Following for the moment the four color theory, the hues would be represented by the central square and would have the four primary colors, red, yellow, green, and blue at the corners, and the other spectral colors would lie between them. The oranges are on the line between red and yellow, the yellow-greens between yellow and green, and so on. At the bottom is black, and at the top white. The lines joining the square with the top and bottom represent the tints and shades. When a red wave is increased in intensity above the point of saturation, pink, a tint, is seen; when diminished, brown, a shade, is perceived. The central line that connects black with white represents the series of grays. The various degrees of saturation are represented by lines on the central base of the double pyramid from the

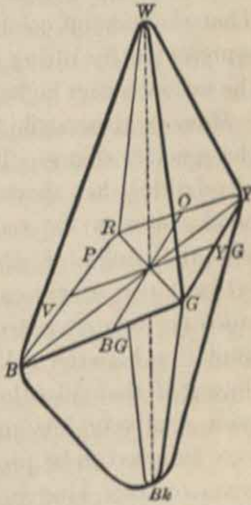

Fig. 47. — Color Pyramid. (From Titchener's "Textbook of Psychology.")

outer square, where lie the spectral colors, to the center that represents the neutral gray. The color tones are more and more mixed with the neutral tint from the circumference inward until color altogether disappears in the center. The fact that the color may be mixed with a gray of greater or less brightness and so reduced in saturation and changed in brightness at the same time, can be represented on the pyramid by lines from the base of our double pyramid to a point on the central line at any distance above or below the base. That the spectral colors are of different brightnesses has been represented by tilting the square base more or less, making the yellow corner higher than the blue.

Hue. — Most striking is the series of hues that compose the spectral colors. The spectrum gives a continuous series of qualities that shade over into each other with no definite break between the red excited by the longest wave length and the violet of the shortest. Any color intermediate between two others can be seen to be similar to both, provided the two are not chosen too far apart. This fact of the similarity between colors intermediate between others early suggested that all colors might be regarded as compounded from relatively few primary colors. These primary colors were assumed to be produced by the stimulation of a distinct organ of some kind in the retina. When only one organ is stimulated the result would be a pure color, when two organs are stimulated there would be a mixed color in which both primaries could be detected.

The Laws of Color Mixture. — All theories, ancient and modern, have been an attempt to discover just what these simple colors are, and to determine how they combine to produce the other colors. The first experimental indication of the fact that most colors are compound is obtained from color mixing. Colors may be mixed, either by having two different wave lengths of light fall upon the same spot of the retina at the same time, or, more conveniently, by rotating disks of the colors to be mixed so rapidly that one color appears before the effect of the other has disappeared. Both methods give approximately the same results. The first law of color mixture is that two spectral colors when mixed give a color that lies between them in the spectrum. When the colors lie near together, the resulting color approaches saturation; the farther apart the two colors in the spectrum, the less is the saturation. Not only may we obtain colors of the spectrum from the mixture of spectral colors, but, if different proportions of the extreme ends of the spectrum be mixed, colors are produced that correspond to no single wave length but are nevertheless true color tones of a high degree of saturation. These are the purples, mauves, and other similar qualities. Since they grade from red to violet, they may be regarded as filling the gap between the two ends of the spectrum. For sensation, then, the series of colors can best be pictured as a closed figure rather than as a straight line. The direct psychological evidence for this is that the two ends of the spectrum are more alike than are points nearer together. Violet has a greater similarity to red than has any spectral color beyond pure yellow, and the two ends of the spectrum may be joined by suitable mixtures of the extreme colors.

The Primary Colors. — All agree that the colors we see in the spectrum are due to the stimulation of relatively few processes in the retina. These colors which may be regarded as pure are called primary. What the simple processes are has been in dispute between two opposing groups of theories. One, represented by Young, Helmholtz, and their followers, makes the facts of color mixing fundamental and assumes that one need postulate as primary no more colors than suffice when mixed to give all of the spectrum. Three colors satisfy this condition. Of the possible groups of three, they select those that produce all of the others in the maximum of saturation. These are red of the end of the spectrum, green of approximately 526, and blue or violet of 475–430 λ. Maxwell developed a series of equations and a geometrical scheme to represent not only the fact that the three colors would when combined give the spectrum, but also indicated the amount of each primary color required to produce the actual spectral color. This color triangle is shown in Figure 48.

The Primary Colors of a Four Color Theory. — A theory that would make four primary colors the basis for the composition of the spectrum was suggested first by Leonardo da Vinci and has been supported on the more physiological side by Hering. Hering's four colors also, when combined give the spectrum and in even greater saturation than the three colors. He chooses a red which is a combination of a little blue with the spectral red, a yellow of 575 λ, while the green is of 495 λ and blue of 471 λ. The spectral values for red and green in particular are relatively uncertain since they vary somewhat for different observers. But it will be noticed that the green is of a considerably shorter wave length for Hering than for Helmholtz. Helmholtz' green would be a yellow-green for Hering, while his red would be a yellowish red. Hering states that the reason that Helmholtz asserted that red and green combine to give yellow was because Helmholtz chose both red and green with a yellowish hue, and when mixed red and green cancel, leaving the yellow predominant. Hering appeals to the immediate inspection of the spectrum in confirmation of his four colors. He asserts that in the spectrum one can see yellow in all colors from the long wave end of the spectrum to the green; that red can be detected in all colors to a pure yellow; that just beyond the pure yellow green begins, and there is a combination of yellow and green until one reaches the pure green. Beyond pure green, blue appears in combination, and the bluish greens extend to the pure blue. Beyond pure blue, the blue is tinged with the red of violet, which becomes more reddish to the short end of the spectrum. The assertion that yellow is primary is the most important distinction between the four and the three color theories.

The first law of color mixing, then, is that all spectral colors may be obtained by mixing three simple colors. This is

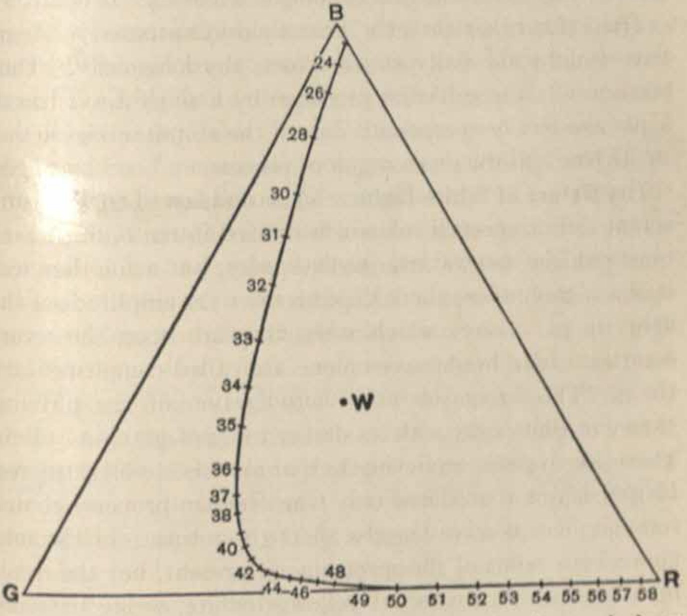

FIG. 48. — Color triangle to show the relation between the mixtures of primary colors and the actual spectrum. The primary colors mixed give varying degrees of saturation. Where the curve corresponds with triangle, as from red to yellow-green, mixtures of primaries give saturated colors. From the rest the mixed colors are unsaturated and so are plotted within the triangle. (After Abney and Watson.)

demonstrated, first, by the fact that colors similar to those produced on the retina by single wave lengths of light can also be excited by stimulating the retina with two different wave lengths suitably chosen; and secondly by the fact that the purples, which physically are always mixed colors, seem just as true colors as those produced by a single wave length. Whether they choose three or four colors as primary, it is assumed by all theories that there are separate substances or processes in the retina for each of the primary colors, and that these simple structures or processes combine their effects in some way in the production of composite colors. It is further asserted that other than the primary colors aroused by single wave lengths are really mixed colors, physiologically. Thus blue-green in the spectrum produced by a single wave length is physiologically compound, due to the simultaneous action of the blue and the green organ or process.

The Nature of White Light. — A second law of color mixing is that certain spectral colors when mixed in the right proportions produce, not an intermediate color, but a colorless sensation, a gray, whose shade depends upon the amplitude of the light waves. Colors which, when they act upon the retina together, excite brightnesses alone are called complementary colors. This brings us to a consideration of the physical nature of white light with its darker tones of gray and black. There are no single wave lengths that give rise to brightnesses. Brightnesses are produced only when certain properly chosen combinations of wave lengths affect the retina. In the sunlight all the colors of the spectrum are present, but the result for sensation is a somewhat yellowish white, owing to dominance of the yellow lights.

Complementary Colors. — To produce white, the simple wave lengths must be present in the right number and proportion. Both theories assume that white or gray light is produced when all of their primary colors are present in the proper balance. Helmholtz asserts that the white light is produced when all three primary colors act upon the retina at the same time and in the right proportion. Hering asserts that white is due to an independent structure or organ and is seen whenever it is not obscured by the color processes. He arranges his primary colors in pairs, red with green and blue with yellow and assumes that the pairs nullify each other when they act together upon the retina. This elimination of color makes possible seeing the effects of the white organ which is excited by all light waves without reference to their length. On both theories when two lights are mixed there are nearly always present complementary wave lengths. These give rise to white and the white reduces the saturation of the mixture. The list of wave lengths of colors that are complementary is given in Table I. It will be seen that no simple statement can be made of the relation of the wave lengths of complementary colors. Each must be determined for itself. As a result of the facts stated in this law it may be asserted that each color has a complement, that all colors go in pairs, although the colors in the middle of the spectrum have non-spectral colors as their complements.

TABLE I. — TABLE OF COMPLEMENTARY COLORS FOR TWO OBSERVERS

OBSERVER VON KRIES		OBSERVER VON FREY	
Long Light Wave in μμ	Complementary Short Wave	Long Light Wave in μμ	Complementary Short Light Wave
656.2	492.4	656.2	485.2
626	492.2	626	484.6
612.3	489.6	612.3	483.6
599.5	487.8	599.5	481.8
587.6	484.7	587.6	478.9
579.7	478.7	586.7	478.7
577.6	473.9	577.7	473.9
575.5	469.3	572.8	469.3
572.9	464.8	570.7	464.8
571.1	460.4	569.0	460.4
570.4	440.4	566.3	440.4
570.1	429.5	566.4	429.5

Negative After-Images. — Two other phenomena of color emphasize the opposition that is present in complementary colors. These are negative after-images and contrast. After-images are of two kinds, the positive, which persist for but a short time and are difficult to see, and the negative, which interest us for the moment as indicating the way the pairing, obvious in complementary colors, runs through all of the facts of color. If one looks for a few seconds at a bright color and then at a gray screen of moderate brightness, one may see for an instant a color of the same hue, but fainter, and then a much more distinct color of a complementary hue. If one looks at a red patch for three seconds and then at the screen, the red color will persist for a fraction of a second, but will probably not be noticed by the untrained observer. Then if one continues to look for a second or so, a distinct green light will appear and persist for several seconds. The length of time that it lasts depends upon the intensity of the original color, upon the duration of the stimulation, and upon various other factors including the fatigue of the eye or of the man as a whole. After-images are more evident when an individual is very tired. If the original stimulating color is a compound, each of the components will have its after-image and the after-image will be a mixed color. Thus purple gives a yellow-green after-image since it is a compound of red and blue; and orange, a mixture of red and yellow, gives a greenish-blue after-image. The explanation of the after-image we may leave to the discussion of color theories. We shall also have to consider later the fact that there are after-effects of color stimulation other than the positive and negative after-images. We desire to emphasize here only the existence of the negative after-image as another indication of the fact that colors are paired as complements.

Color Contrast. — Every color that stimulates the retina not only stimulates the area upon which it falls, but also induces its complementary color in a zone immediately about it. The stimulation of the surrounding area is known as contrast. Thus the shadows upon a green lawn are seen by the artist as purple, shadows on the snow are blue, from the yellow sunshine. Contrast colors are not always readily seen without practice. We know from past experience with the object what the color of the surface is and correct the actual sensation by that knowledge. We see an object as we know it must be, not as the impressions on the retina would make it. The contrast colors are seen most readily under circumstances in which the real color of the object is not apparent. If one place a strip of gray on a large sheet of red paper it will take on a greenish hue. If this is not at once apparent it can be brought out by covering the larger sheet with thin tissue paper. Seen through the covering paper, it is not so readily appreciated that the strip is really gray, and the contrast green becomes apparent. Shadows also permit the contrast colors to be seen readily. Place a lighted lamp or candle in a room where daylight comes through a window and bring a pencil near. Two shadows will be cast. The one cast by the lamp will take on a bluish tinge, in contrast with the yellow of the lamp. The laws of contrast are much the same as the laws of after-images. They are so similar that one has been called simultaneous, the other successive induction. The intensity of the induced color depends upon the size of the inducing surface, the vividness of the color, and the distance from the inducing surface.

Color Blindness. — A series of facts of great importance for color theory and for practical life is that certain individuals lack vision for parts of the spectrum, and very rarely a man is found who can detect no colors at all and can still see brightness. Studies of 2000 school children by von Planta showed that 7.9 per cent of the boys and 0.43 per cent of the girls were in some degree defective in color vision. About one person in 40,000 is said to be totally color blind in that he sees no colors at all. The spectrum appears to him to be a band of gray of different brightnesses. Color-blind individuals are aware of their defect only as they find that they cannot distinguish differences that are apparent to normal individuals. Most common are defects in seeing red and green. Red will be confused with green and both are confused with yellow. Very rarely, cases of defects in the vision of blue or yellow are found but these have been studied so little that few statements can be made concerning them. Theory has influenced observation of these cases so much that it is not safe to make many statements concerning color blindness until we have brought together a number of other facts. We shall here give only these few preliminary facts.

Peripheral Vision. — Closely related to the phenomena of color blindness is the vision on the peripheral retina of the normal eye. It may be said that every eye has in it a red-green blind area and a totally color-blind area. If one fix the eye upon a point and then have an assistant move a bit of colored paper away from the fixation point, the color will be seen to change when the paper is twenty to thirty degrees away from the fixation point. One can see the full range of colors only for twenty or thirty degrees from the fovea; the distance varies with the individual and with the diagonal that is used. Experiments show that red and green are the first to disappear as the paper is moved away from the center, yellow and blue next. The two members of each pair do not disappear at the same place as the Hering theory would require if it were to hold strictly, but the red and green disappear before the blue and yellow. The upholders of that theory explain the discrepancy as due to incidental effects. The point of vanishing can be shown to vary with the saturation and brightness of the color, with its size and the contrast with the background. The advocates of the Hering theory assert that failure of the complementary colors to disappear at the same place is due altogether to unnoticed differences in these conditions. Irrespective of the bearing upon special color theories, it is a highly important fact that there are these partial and total color-blind areas in the periphery of the eye. In harmony with the distribution of sensitivity where it will be most used, it is found that color vision extends farther in the lower and outside of the field of vision than it does on the upper and inner portion of each field.

Summary of the Facts of Chromatic Vision. — To bring together the facts of the chromatic series of sensations, we may say that the complete range of colors may be regarded as compounded out of relatively few simple qualities, how many is still violently discussed. At least, all of the 200 to 1000 distinguishable spectral colors can be produced by mixing three or four simple colors. The colors are related in such a way that each color has a complement, which, when added to it, will give gray. This complement is also seen after the color has stimulated the retina — the after-image. The complement is also induced on the area of the retina around that stimulated (contrast). The primary colors may be lacking from birth in the case of certain individuals whom we know as color blind. They also are not present in the periphery of the retina. All these facts indicate the importance of a few primary colors and the intimate connection of a color and its complement.

The Achromatic Series. — The achromatic series is less rich in sense qualities. It contains only the series of grays, ranging from black to white. There are no breaks or turns in it as in the color series. Like the color series it shows the phenomena of positive and negative after-images, of contrast, and of mixture, in so far as two grays when mixed give an intermediate shade. A dark patch will be seen after a bright light has stimulated the eye. There is a halo of bright light about a dark patch. The brightness or achromatic sensations have been explained as due to the combination of complementary colors or as due to the mutual cancellation of the color and its complement or both. All admit at present that the achromatic sensations under many circumstances arise from the stimulation of a special organ. In addition to the production of gray by the combination or cancellation of complementary colors, there are four conditions under which brightness alone may be made apparent: (1) by reducing the intensity of the light; (2) by reducing the size of the area affected; (3) by reducing the time of stimulation; (4) by stimulating with any wave lengths the periphery of the retina or a totally color-blind retina. These facts have been adduced by the supporters of the theory that brightness is seen when the chromatic processes cancel each other to show that there is an independent brightness organ. This organ is assumed to be stimulated in isolation and so to have its effects appreciated whenever the color processes cancel; when the light is too faint to arouse the color organs, but will still stimulate the brightness organ; when the duration is too short to arouse the color processes; and where the color organs are absent as on the periphery and in the color-blind eyes.

The Duplicity Theory. — During the last score or more years the importance of the study of the achromatic series has been greatly emphasized and the interpretation given the facts greatly modified by the discovery of a series of facts that has led to the acceptance of the existence of two distinct organs of vision for brightness rather than merely one. One of these is found in the cones, and senses the brighter lights alone; the other is in the rods, and is active primarily in faint light. The fact already noted that the fovea has cones alone, while the extreme periphery has rods alone makes it possible to study the results of stimulating one without the other. The cones have been proved to differ from the rods in their functions in three ways. (1) The rods are much more sensitive to faint light than are the cones. This probably is due in large measure to the fact that the rods contain the visual purple while the cones lack it. (2) The rods respond to all wave lengths by brightness alone, while the cones respond to different wave lengths with different colors. (3) The rods are more sensitive to the short wave lengths, the cones to the long wave lengths. These differences which are accepted today by the upholders of all theories have been found extremely important in explaining many of the phenomena of color blindness, and in other fields. It has found confirmation in many different investigations.

Adaptation in Faint Lights. — The observation of the changes in sensitivity after a long time in the dark are important for their bearing on the duplicity theory. As one goes into a dark room one changes from the cones to the rods as the organ of vision. The most striking phenomenon of adaptation is the great increase in sensitivity of the retina after a period in the dark. After an hour in the dark the eye is about 100 times as sensitive as it is in ordinary daylight indoors and from 100,000 to 150,000 times as sensitive as it would be after a long period in the bright sunlight. Adaptation continues for as much as sixteen hours, but is most rapid in the first few minutes and is relatively slight after the first hour. It is probably due in very small part to the expansion of the pupil, but for the greater part to the visual purple, which regenerates after a time in the dark and by some chemical action increases the sensitivity of the photochemical tissue in the rods. The fovea in an area of about two degrees in diameter shows little adaptation to the dark. It undergoes a quick adaptation for two or three minutes and then remains constant. In the dark-adapted eye the most sensitive point on the periphery according to Nagel may be 1000 times as sensitive as the fovea. In daylight adaptation the fovea is 20–40 times as sensitive as the periphery. It is for this reason that one can see a faint star better if one does not look at it directly but sees it out of the corner of the eye. Adaptation is almost entirely restricted to the rods.

Disappearance of Color with Reduction of Intensity of Light. — A second fact that gives evidence of the difference in function between rods and cones is the change in the colors of the spectrum as illumination is reduced. These changes are of two kinds — in the hue itself and in the brightness of the color or of the gray that replaces it. The more noticeable of these differences between the spectrum as seen at the intensity of ordinary daylight and in the faint light of a dark room is that the colors are altogether lacking at the low intensities and the spectrum appears as a band of gray light. As the intensity is diminished, the colors disappear in different orders. The reds and violets vanish first and the orange is the last to go. Mixed colors change their hue with the reduction of the light. Scarlet becomes orange, orange, more yellow, and blue-green shifts towards blue. With the exception of extreme red, the colors are seen as brightnesses after they disappear as color. Blue has the longest of these colorless intervals. This so-called ‘photo-chromatic interval’ is not present at the fovea. There the colors are not seen as grays after they cease to stimulate the retina as colors. This leads us to believe that the colors are seen by the cones alone; brightnesses of low intensities are seen by the rods. Where the rods are lacking there is no gray that persists after the colors cease to be seen.

The Purkinje Phenomenon. — The evidence for the duplicity theory from the change in brightness of different parts of the spectrum as intensity is diminished is quite as marked. If a red and a blue seem of equal brightness in ordinary daylight, the blue will be much brighter in reduced illumination. The short wave lengths have a much greater effect upon the rods which are active in the faint light. In this they stand to the cones much as the photographic plate, which registers the shorter blue waves but not the red or longer waves, to the eye as a whole. In daylight the brightest point in the spectrum is in the yellow, λ 600 *ca.*, while in faint light the brightest point shifts well towards the green λ 540 *ca.* This shift is known as the Purkinje phenomenon.

The Purkinje phenomenon also appears in the comparison of single colors. If one have a red disk and a blue disk, and add enough gray to the brighter to make the two identical when rotated in a bright light and then reduce the light until the colors disappear, it will be seen that the blue appears much brighter. This effect shows even where the lights are combined in a gray which altogether disguises the color. If one gray be mixed of long wave length, red and green, and another of blue and yellow and these grays be made of equal brightness in daylight, the gray compounded of long wave lengths will be much darker in faint light. It should be said that in light sufficiently faint to give the Purkinje phenomenon, the colors will not be seen as colors, but merely as brightnesses. The spectrum in faint light is a band of gray with a relatively bright spot where the green would be in bright light. It is asserted that the Purkinje phenomenon is not present in the fovea. On this point observers disagree. There is great difficulty in making sure that the fovea alone is used in observations of this kind. These three phenomena — different adaptation in periphery and fovea, the lack of color in faint light, and the Purkinje phenomenon — are all to be explained on the assumption that both the rods and the cones give gray, but are differently sensitive to long and short waves. The grays are of approximately the same quality. The only difference noticed is that according to von Kries the gray from the rods has a slightly bluish tone.

Color Blindness and the Duplicity Theory. — The duplicity theory receives much support from the facts of color blindness and also aids in interpreting some of the observations of color-blind cases. The most important support of the duplicity theory is that totally color-blind individuals give evidence that they have lost the functions of the cones altogether and see only with the rods. Three facts seem to confirm the view that total color blindness is due to rod vision alone. Most striking is a total blindness in the fovea where the normal eye has only cones. This foveal blindness causes the patient to move his eyes continuously in a vain effort to find a point of best vision. This is known as nystagmus. Foveal blindness has not been demonstrated in all totally color-blind individuals, but is present in many. A second fact is that the relative brightness of different wave lengths is the same for the color blind in daylight as for the normal eye in twilight. The long waves of the spectrum at the extreme red end are not seen at all, and those long wave rays that are seen are relatively much darker than for the normal individual. A third fact is that the totally color-blind patient is very sensitive to bright lights and avoids them when he can. Opposed to these individuals who have only rods is another relatively small group of individuals who apparently have only cones. They have almost no twilight vision, are entirely at a loss after dark, and in daylight can see relatively little except directly in front. They do not show the Purkinje phenomenon. When a light loses its color it is not seen as gray. They are known as hemeralopes. Cases of this sort are rare and have not been studied as intensively as they deserve.

Partial Color Blindness and Cone Vision. — The discussion of partial color blindness has also taken a new turn since the duplicity theory developed. While all are now agreed as to the explanation of total color blindness, there is still a question between the upholders of the three and four color theories as to partial color blindness. The supporters of the three color theories, of whom von Kries is most prominent, assert that one may lack either red or green and rarely blue. The four color theory of which Tschermak, following Hering, is now the most prominent exponent, holds that red and green are the product of one organ and that one cannot be lost without the other. A second difference between the theories that might be given an empirical test is that the four color theory asserts that yellow is seen when red and green are absent, while the followers of Helmholtz insist that yellow is dependent upon the stimulation of both red and green and could not be seen if either is lacking.

The difficulty in settling these points is primarily that the color-blind individual cannot say directly what sensation he receives from a stimulus. He has never had the sensation he lacks and so does not have a name for it, and has no appreciation of what the normal man sees. As a consequence you cannot determine if a man is color blind by asking him if he sees a color or even asking him to name objects. He may name colors fairly accurately on the basis of the name he associates with a particular shape or a particular brightness and still be shown by more careful tests to be defective. The methods used consist in asking an individual to compare colors and say when two combinations are alike. The simplest is to give the patient a number of skeins of colored yarn and ask him to put those that are alike in the same pile. If color blind, he will put reds and greens and yellows together. A more accurate method is to show him a color compounded of red and blue lights, and ask him to compare them with an intermediate color. He will assert that mixed pairs resemble the intermediate color when the combination will be very different for the normal eye.

All agree that a combination of red and green will be matched for the color blind by a yellow provided the two be suitably graded in intensity. One group of partially color-blind individuals will require more of the red, the other more of the green to seem the same as the yellow. The advocate of the three color theory holds that observations prove that one type of individual is green blind, another red blind. The four color theorist on the other hand holds that both the red blind and green blind types of the three color theory see yellow but uses the duplicity theory as evidence that the difference is that one sees a dark yellow, the other a bright yellow. The red-blind individual is said to see a much darker color than the others, since he has predominantly the twilight values as regards brightness, while the green-blind individual sees the red or long wave lengths as brighter as in the normal daylight vision. It is argued that both see yellow, but one sees a darker, the other a brighter yellow. This agrees with the actual

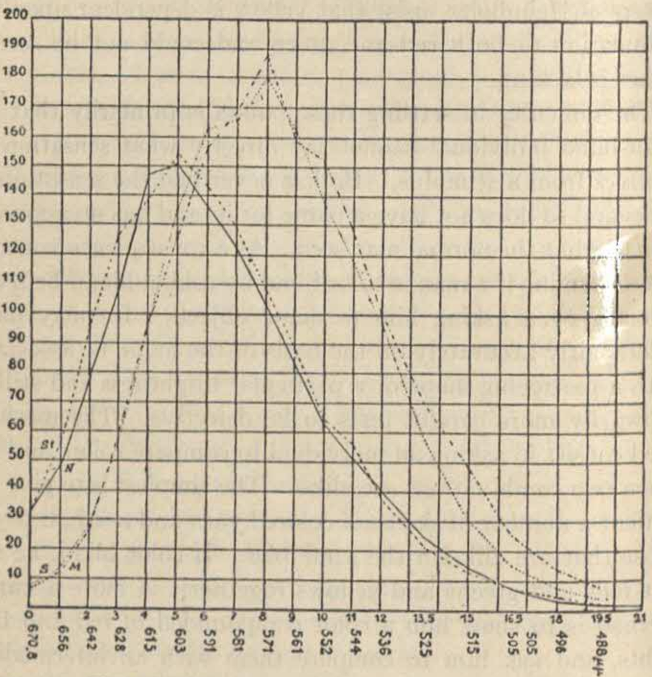

FIG. 49. — Chart showing relative brightness of red light in the spectrum of gas light for two protanopes, *S* and *M*, and for two deuteranopes, *St* and *N*. (From von Kries.)

observations of von Kries, an upholder of the three color theory, although he interprets his results to show that one is defective in red and sees green, the other lacks green and sees red. To avoid the ambiguities of the older terms von Kries has suggested that those individuals who see the spectrum in the relative brightness values of normal individuals in daylight be called deuteranope, those who see it in twilight values shall be called protanope. The brightness values are the same for the protanope, for the totally color blind, and for the twilight vision of the normal eye. On the other hand, the brightness values of the spectrum are also the same for the deuteranopes, the normal eye in daylight, and the periphery of the normal eye. The difference between the normal eye and the protanope may be seen from the accompanying charts from von Kries (Figs. 50, 51).

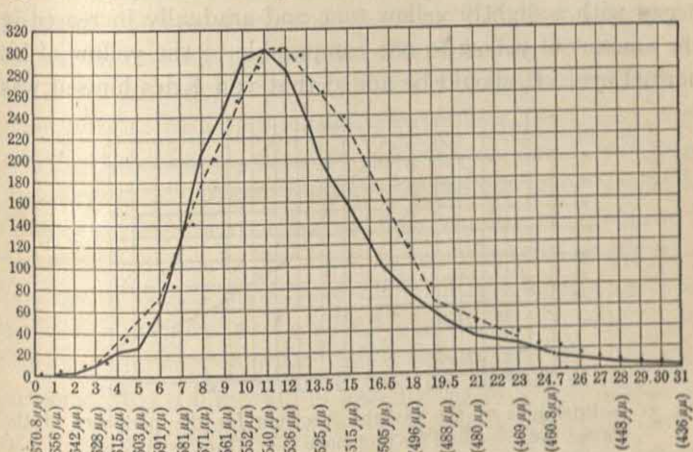

FIG. 50. — Brightness of prismatic spectrum of gas light for total color blind ----, and for twilight vision of normal eye ——. Comparison with Figure 49 shows that both have the same value as the protanope. (From von Kries.)

A final settlement of the controversy is not yet in sight. Evidence in favor of the actual seeing of yellow rather than of red or green is presented by Koellner on the basis of a case reported by von Kries of an individual, who was partially color blind in one eye, normal in the other. He could therefore report on what the color-blind eye saw on the basis of the sight of the normal eye. He reported that the long wave end of the spectrum seemed to his normal eye to begin with red and to shift gradually to yellow. For the color-blind eye the colors began with a slightly yellow tone and gradually increased in the amount of yellow to one comparable to the yellow of his normal eye. It should be added that von Kries himself was not changed in his acceptance of the Helmholtz theory by this observation. We must apparently leave the controversy between the advocates of the three and four color theories unsettled as to whether a protanope sees yellow or green and a deuteranope sees yellow or red. It is an important point of agreement that all admit that the protanope sees the red end of the spectrum as much darker than does the deuteranope and as much darker than the green, while the deuteranope sees the spectrum in very much the same brightness values as the normal eye in daylight. The phenomena of color blindness, both total and partial, constitute strong confirmation of the duplicity theory, even if they do not constitute a definite criterion for deciding between the three and four color theories.

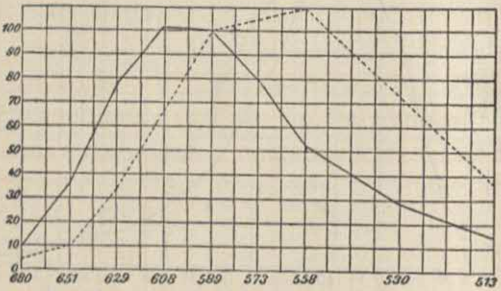

FIG. 51. — Brightness of the gaslight spectrum for the periphery of the normal eye ——, and for protanope ----. (From von Kries.)

Temporal Phenomena of Vision. — The characteristics of a color depend in many ways upon the duration of the color stimulus. Stimuli do not produce their maximum effect at once, nor does the color cease at once with the excitation. There is always a rise to full effect and a gradual disappearance. The course, as has been shown by Miss Bills, is different for each of the colors, both for the period required to attain its maximum, and for the period of decline. The curve varies for each color and for the different intensities of the color. At the lowest intensity used, the order was yellow, red, green, and blue; for the medium intensity it was yellow, green, blue, red; and for the highest intensity, yellow, red, green with blue undetermined.[1] These results were obtained in the dark. They may be different for daylight conditions. When the sensation reaches its maximum, even when the stimulation persists, it begins at once to diminish its intensity, at first rapidly, and then very gradually until all colors disappear. This gradual loss of color, called adaptation, can be easily demonstrated if one will but gaze fixedly at a small square of color. Losing awareness for the color of the glass when colored glasses are worn illustrates the same phenomenon. Black and white show both inertia of stimulation and of its cessation, and also adaptation. The rate of adaptation varies with the color, so that one component after another may vanish.

After the stimulus is removed, the excitation continues for a moment to be of the same quality as the original, and then gradually dies out. This persistence is called the positive after-image. The dying out corresponds to the period of rise of stimulation. Both may be regarded, and are regarded in all theories, as an expression of the inertia of the color processes. They require time to start and to stop. For a fraction of a second the color or gray persists in approximately full brightness. It is this fact that makes possible the mixture of colors on rotating disks. The excitation of one color persists during the excitation of the retina by the other. For practical purposes the effect is the same as if both lights were active at the same time, and the brightness effect produced is the average of all the lights that are stimulating the eye during the period. If the rotation is less rapid, one obtains a rapid fluctuation in brightness, the flicker. This flicker disappears at a lower rate of rotation when colors are of the same brightness than when they are of different brightnesses. The flicker makes it possible to compare directly the intensity of different colored lights, a problem that produces difficulties for ordinary photometric methods.

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[1] Bills, "The Lag of Visual Sensation," Monograph Supplement of the *Psychological Review*, vol. 28.

The positive and negative after-images are only the more easily observed of a series of images. At least six images, some observers report eight, have been reported. If one will turn on an electric light in a dark room for an instant one can see readily many of these images. First comes the positive after-image of the color and brightness of the stimulus. Second is a black image. Third follows a light impression of the color of the object, followed (4) by another dark image. Fifth comes a bright image of complementary color to the stimulus, easy to see and sometimes called the satellite. It is followed by a dark image. More difficult to see are a seventh image that is rather light and an eighth that is dark. These images are assumed to be due to the tendency of the retinal elements to respond rhythmically. Some authorities have assumed that some of the images may be due to action of the rods, others to the activity of the cones. A stimulus arouses one. It acts for a brief period and then ceases to act, while the other with a different rhythm will be active. Thus there may be assumed to be an alternate activity and cessation of activity in the two structures which give rise to the successive images.

Chromatic After-Effects of White Light. — Interesting also is the fact that it is possible to excite colors as an after-effect of brightness. If one will look for half a second or so at the setting sun and then for a time watch the after-image as projected against a neutral surface, one will observe a slow succession of colors and grays that will last for several minutes. Helmholtz gave the order, with the eyes open, as white, red, green, red, blue. One notes in this, too, that the color of an image depends upon the character of the background. It will have a different color with the eyes open and with the eyes closed. When the eyes were closed, Helmholtz found the order to be blue, green, yellow. If one has a red image with the eyes open and closes the eyes, the image changes to green. In many cases, but not universally, the dark ground image is the complement of the bright ground image. It will also be noticed when a disk with sectors of black and white is rotated slowly that a series of faint colors will follow the edge of the black sector. Probably in the same general class are the colors produced when a white disk with concentric rings of black is rotated. If the so-called Benham disk, of which one type is given in Figure 52, be rotated slowly the inner ring appears to be purplish, the outer greenish. The colors depend upon the length of the black lines, among other factors. The explanation of

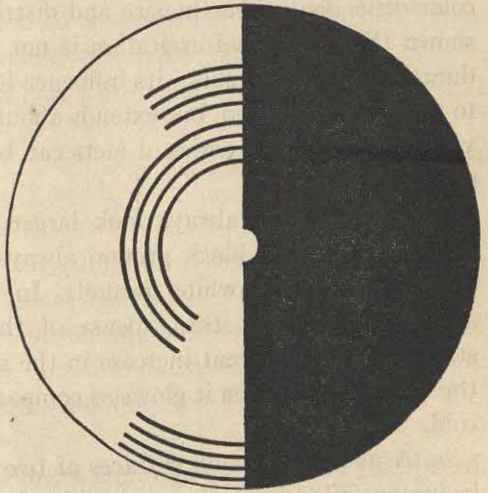

Fig. 52. — Benham disk.

this group of phenomena is not yet agreed upon. They must in some way be referred to the stimulation of the color processes by bright light. Granted this and the demonstrated fact that each color has a rate of rhythmical appearance and disappearance different from the rate of every other color, the direction that a theory must take becomes evident.

The Spatial Phenomena of Vision. — Similar to these effects of duration upon color effects are a number of variations of color dependent upon the size and distribution. It has been shown that the visual excitation is not limited to the actual duration of the stimulus; its influence is similarly not limited to the area stimulated, but extends about it in all directions to varying extents. A series of facts can be adduced to demonstrate this.

1. Bright colors always look larger than dark ones. A white square on a black ground always looks larger than a black square on a white ground. In each case the white stimulus spreads at the expense of the black. Still more striking is the apparent increase in the size of the filament of the electric light when it glows as compared with its size when cold.

2. A number of small surfaces of two or more colors when in juxtaposition fuse into a color identical with that given by the same colors when mixed by rotation. Each color extends beyond the area stimulated, and these extensions overlap to produce a continuous color of the average hue and brightness of all. The overlapping in space is similar to the overlapping in time in mixtures produced by rotating disks. In many fabrics it will be noticed that the dominant color seen at a distance is a mixture of a number of threads of different colors.

3. A colored surface may be too small to be seen as colored and may yet be seen as gray. Colored objects at a distance lose their color while still visible. The size at which the color disappears varies for different colors. The table below gives

the diameter of five colored papers at which the surface will be seen as gray in the first column and at which its color will be seen in the second. The column headed "Ratio" gives the proportion between the areas that can be seen at all and the areas that can be seen as colored. It will be noticed that a red surface, which is large enough to be seen at all, is seen as red, while a much larger area of blue is seen only as gray. Several bits of color, each too small to be seen alone, will when close together induce a color sensation. The explanation is the same as for the second law above.

Color[1]	Absolute Limen	Color Limen	Ratio
Extreme red	0.5	1.0	4
Orange	0.9	2.1	5.5
Yellow	1	3.1	9.6
Green	0.3	4.2	196
Blue	0.3	7.5	625

4. In some degree, size, duration, and intensity are interchangeable. More intense lights seem larger, seem to last longer, and, *vice versa*, within limits larger surfaces and longer exposures seem to give more intense stimulations. Up to two minutes in angular size doubling the intensity doubles the apparent size.

These various phenomena are to be explained by the spread of the effects of the excitation in the retina, either by a spread of the chemical effects from one unit to another, or by a spread of nervous impulses from the cones or rods stimulated to neighboring ones. This spreading may take place through the connecting neurones just inside the layer of rods and cones. (See p. 108.) Contrast is due to a similar phenomenon, but has been described above. In that case the color induced in the surrounding area is the complement of the stimulus color.

The Helmholtz Theory. — A brief statement of the more important theoretical explanations of color may serve as a review of the facts. The first of the modern theories was formulated by Thomas Young, an English physicist, and expanded by Helmholtz. It assumes that there are three separate kinds of organs in the retina, that one of these is affected most strongly by red, another by green, and a third by blue or indigo. White is compounded of the effects of all three stimulated together. The original theory stated that white could be seen only when all three organs were present and were stimulated. At present its advocates accept the duplicity theory and have an independent white when the rods are active. Since the duplicity theory has been accepted, they have said relatively little about the way white is seen in bright light. They do recognize a separate white from the cones, which presumably is still assumed to be a mixture of the colored lights. Yellow is the result of simultaneous stimulation of the red and green organs. When all three are excited at once, white is produced. Red and green when stimulated together give rise to yellow. All the other colors are produced by the mixture of the effects of two or all three of the organs. After-images are due to the fatigue of some of the organs and the response of those remaining when white light falls upon the retina. Contrast is an illusion of judgment.

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[1] From Charpentier, *Annales d'ocul.*, lxxix, 1878.

Objections have been raised against the Helmholtz theory on most of the points. (1) It is asserted that white cannot be compounded of red, green, and blue, since it can be seen where no one of its components is present as in the periphery of the eye. This white is not the typical rod white since the relative brightness of the white induced by different wave lengths corresponds to the daylight, not the twilight, values. Similarly, if white were a compound a red blind individual would see white as a greenish blue. A man color blind in one eye only, who knows what white is like from his normal eye, asserts that he sees white with his color-blind eye. (2) The case for an independent yellow is not clear, as was seen in connection with color blindness. (3) The explanation of after-images would fail if white is not compound. It is argued, too, that an after-image is much too positive to be explained as a mere subtraction effect. (4) Contrast is certainly not an illusion of judgment or other central process for it is seen most readily where the inducing color is not noticed. Inference prevents appreciation of a contrast color rather than aids it. (5) One can argue from the Purkinje phenomenon that no three color combination can produce white or gray. According to the measurements the long waves give a relatively bright effect in daylight and a dark effect in twilight. On a three color theory the total stimulations of the three color organs that produce white must always be the same. It is highly improbable that each of the primary color organs would be stimulated in the same degree by each of the two combinations of wave lengths when mixed the one from long, the other from short wave lengths. On a four color theory gray can be mixed by suitable combinations of two colors. One of these would necessarily be of a different average wave length from the other. When seen in twilight the longer wave length combination would appear darker than the short wave combination. This corresponds to the results obtained when two grays composed of different wave lengths are compared first in daylight, then in twilight.

The Hering Theory. — The Hering theory asserts that there are two pairs of primary colors with the elements in each pair opposed, and an independent brightness organ. The theory assumes that each pair of colors is produced by antagonistic changes in the same organ. One organ gives rise to red and green, a second to blue and to yellow, and a third to the brightnesses, black and white. The antagonistic processes are said to be anabolism and catabolism, the upbuilding of the organ and its deterioration. Green, blue, and black induce anabolism, the others catabolism. Complementariness is explained by the fact that members of the same pair of colors tend to induce opposed processes in the same degree and so produce no effect on that color organ. When the tendency of green to produce anabolism and of red to cause catabolism are equally strong, no change in the organ results. Since all wave lengths stimulate the brightness organ, gray is seen, and seen alone, when the colors cancel each other. Color blindness is due to an absence of one or more of the organs. The red-green organ is most frequently lacking. Red-green blindness is most frequent, and red and green are least widely distributed on the retina. In total color blindness the yellow-blue organ is lacking also, the white-black organ alone is present. Positive after-images are explained as due to a continued action of the organ after the stimulus has ceased. In the negative after-image anabolism is followed by catabolism, since the excess material accumulated by the retinal excitation tends to disappear as the light ceases to act and the tissues return to their normal balance. Similarly, catabolism is followed by anabolism when the stimulation ceases. Contrast is due to one metabolic process producing its opposite in the surrounding areas. Excessive anabolism in the stimulated area tends to draw nourishment from the surrounding area and so produce catabolism in the area about.

Criticism of the Hering Theory. — The most obvious objection to the Hering theory lies in its assumption that the processes of anabolism and catabolism are fundamental for the explanation of colors. Nowhere in the bodily activity does anabolism result directly from stimulation. We know so little of the mechanism of the structures in the eye that any theoretical construction is likely to be wrong, and the more specific the theory, the more open to objections. The assumption of four color processes, that they are in some way paired and that the pairs act in opposition to each other instead of by combination, has many advantages. The detailed explanation is not so attractive. An addition made by Müller to obviate an apparent difficulty in the theory is interesting. Müller thought it inconsistent to assume that simultaneous activity of two phases of the color organs should cancel each other, while equal stimulation towards anabolism and catabolism in the black-white organ should excite the positive neutral gray. Müller assumed that the opposed processes in the black-white organ probably cancel and argued that the gray seen by the rested eye is of cortical origin due to a constant activity of the visual area in the cortex. As evidence for this he cites the fact that the blind, if not blind from birth, always see this gray, and that a spot of gray is seen where even a small area of the retina has been destroyed.

The Ladd-Franklin Theory. — A recent theory of Mrs. Ladd-Franklin gives an evolutionary theory of color vision. She assumes that primitive vision in animals is rod vision which gives differences of brightness only. Later cones develop and with them comes the appreciation of colors. Within the cones there is also a development. First appear substances sensitive to blue and yellow alone, then the substance sensitive to yellow divides into two, one sensitive to red and the other to green. Each more evolved organ may act as a whole to give its original sensation. The cone when stimulated as a whole gives brightness, the red and green acting together give yellow. The color-blind eye is an undeveloped eye. In red-green blindness the yellow substance has not yet subdivided; in total color blindness the cones act only as rods. In several respects it is an ingenious development of the facts that are accepted by both Helmholtz and Hering into an independent theory. Walls has recently found evidence that the cone is the more primitive, the rod a later development. This would be fatal to the theory unless the cones be made primitive, and be assumed to develop rods by evolution. The theory also has not incorporated the principles of the duplicity theory, but they could be added without a very great change.

The Accepted Facts of Vision. — A statement of what would be accepted by all schools as true for vision is difficult in itself and gives a relatively small number of facts. (1) All the colors of the spectrum can be produced by combining relatively few simple colors. Whether the number of primary physiological processes corresponding to these colors is three or four is still disputed. (2) Certain colors are complementary, *i.e.*, when both stimulate the retina in suitable proportion, white or gray is seen instead of the colors. Whether complementary colors combine or cancel each other to give white is still in dispute. (3) Stimulation by one color is followed by the appearance of the complement after a brief interval. (4) The complementary color is also present about the area stimulated. (5) Certain of the primary colors may be lacking to certain individuals and upon the periphery of all eyes. (6) White and grays may be produced in two different ways, by bright lights and by faint lights. The grays seen in faint light are due to stimulation of the rods, those seen in bright light are due to stimulation of the cones. Aside from this difference between rods and cones, no relation has been established between the structures of the retina and any of the functions of sensation.

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CHAPTER V

SENSATION (*Continued*)

AUDITION

THE auditory sensations stand next to the visual, both in complexity and in importance for behavior and mental life in general. We can approach the study of audition in three different ways. Physically, sound is vibration in the air; physiologically, it is oscillation of some delicate membrane in the ear; psychologically, it is the series of sensations, the material of music and human speech on the one hand, and the series of noises and unorganized sounds on the other. The physical processes consist of longitudinal oscillations that proceed outward concentrically from the vibrating body. These oscillations vary in rate, which corresponds to the pitch of the tone; in amplitude, which corresponds to the intensity of the tone; and in complexity, which corresponds to the timbre, or tone-color.

THE STRUCTURE OF THE EAR

The Divisions of the Ear. — The organ that translates these vibrations in the air into nerve processes is the ear. The ear is composed of three parts: the external ear, consisting of the pinna, commonly called the ear, and the external auditory meatus or tube that runs into the head; the middle ear, an enlarged cavity in the skull separated from the external by the membrane of the tympanum or drum; and the internal ear, a labyrinthine cavity between the middle ear and the brain where the vibrations are translated into nervous impulses. The external ear needs no description. The outer ear probably has some influence in collecting the vibrations in the air and turning them into the external meatus. The meatus itself is curved slightly and thus reduces to a minimum the probability of injury to the membrane of the tympanum.

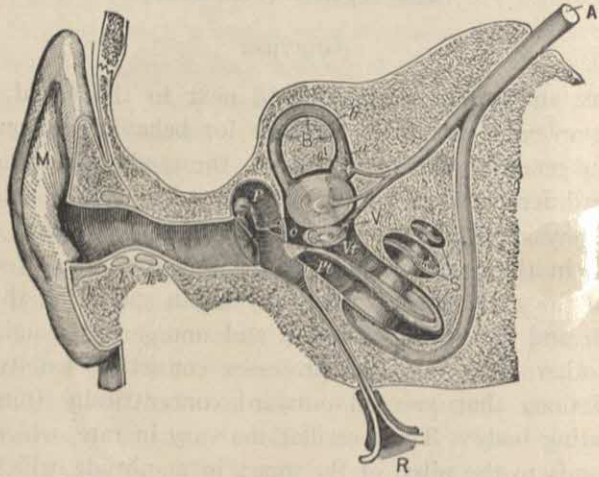

FIG. 53. — Schematic section of the ear; *M* and *G*, external ear. *P*, middle ear with small bones; *S*, cochlea; *B*, semicircular canal; *A*, auditory nerve; *R*, Eustachian tube. To give a sectional view the cochlea is displaced 90°. Its apex should be turned toward the observer. (From Calkins, after Martin-Czermak.)

The important structures of the middle ear are the membrane of the drum, three small bones that stretch across the cavity of the middle ear, and the membrane which with the plate of the stirrup closes the oval window of the inner ear. The chain of bones consists of the malleus, incus, and stapes, named from their shapes, which resemble a hammer, anvil, and stirrup, respectively. The handle of the hammer is fastened to the inner surface of the membrane of the tympanum, the head is jointed into the top surface of the anvil, and is hung by a ligament from the top of the cavity of the middle ear. The anvil resembles a molar tooth. The head of the hammer is jointed to the head of the anvil on what corresponds to the grinding surface of the tooth. What corresponds to one root is connected by a ligament to the inner side wall of the middle ear; what resembles another root is connected by a delicate cartilage to the stapes or stirrup. The analogue of the foot of the stirrup is oval in shape and is fitted by a membrane into the oval window, which closes the inner ear. The membranes and the bones swing together on the ligament as a fulcrum. When the air vibrations impinge on the membrane of the drum, it swings inward, carry-

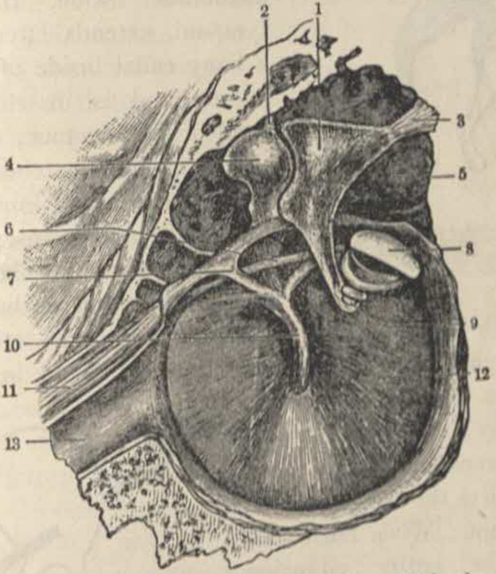

FIG. 54. — Tympanum and small bones seen from within the middle ear. 1, anvil; 2, suspensory ligament of hammer; 4, head of hammer; 7, tendon of tensor tympani; 8, foot-piece of stirrup that fits into the oval window; 10, handle of hammer or manubrium; 11, tensor tympani; 12, membrane of the drum; 13, Eustachian tube.

ing the hammer and the other bones with it, and the foot of the stirrup pushes against the lymph of the inner ear, and sets that in vibration also. Two muscles prevent movements strong enough to rupture either membrane. One, the tensor tympani, extends laterally from a bony canal inside of the tympanum and is inserted in the head of the hammer; the other, the stapedius, extends from a tube in the lower inner wall of the cavity and is inserted by a long ligament in the head of the stirrup near where the anvil is joined to it. The two muscles oppose each other. The tensor tympani tends to draw the drum head inward, the stapedius to draw the stirrup foot away from the oval window toward the drum head and reduces the tension of the tympanum. When both contract, the entire vibrating mechanism is held firm and prevented from making too violent oscillations. Both muscles have been shown by direct registration of their movements to be excited reflexly, and the tensor tympani can be contracted voluntarily by some individuals.

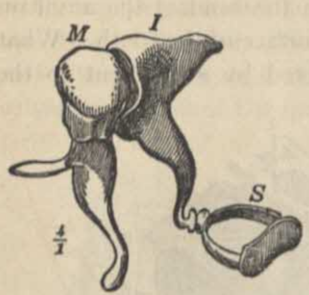

FIG. 55. — The bones of the middle ear. *M*, hammer; *I*, anvil; *S*, stirrup.

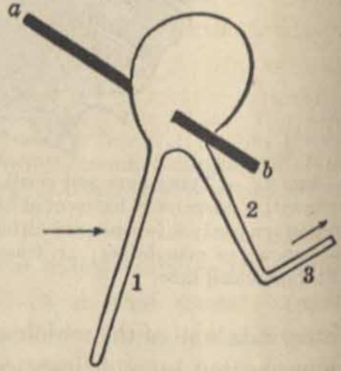

FIG. 56. — Illustrates the way in which the three bones act together as a bent lever. 1, the handle of the hammer; 2, the long process of the anvil; 3, the stirrup; *a–b*, the axis of rotation. (From Howell's "Textbook of Physiology.")

The membrane of the drum, by virtue of its conical shape, the arrangement of the fibers that compose it, and the weighting on one side only, has only a slight tone of its own at about 1200 V D[1] a second, responds to all vibration rates impartially, and so transmits all tones, whatever their pitch, with approximately equal strength. In traversing the middle ear, the amplitude of the waves is decreased and their intensity increased. This change takes place in two ways. First the area of the oval window is much smaller than the area of the drum, so that the energy is more concentrated. Second, as can be seen in Figure 56, the lever arm formed by the handle of the hammer has a greater effective length than that formed by the process of the anvil to which the stirrup is attached. Sound waves, then, traverse the oscillating mechanism of the middle ear with rate or pitch unchanged but with intensity increased twenty to thirty times and with a corresponding diminution in amplitude.

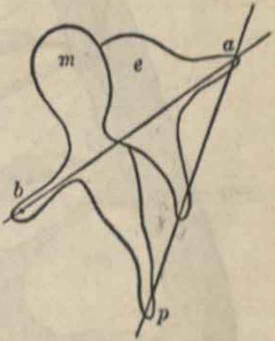

FIG. 57. — To illustrate the lever action of the ear bones. *m*, the hammer; *e*, the anvil; *a*, the short process of the anvil which abuts upon the wall of the middle ear and serves as point of rotation; *a–b*, the power arm; *a–p*, the load arm of the lever.

Connecting the cavity of the middle ear with the throat is the Eustachian tube. This tube permits keeping the air of the middle ear at the same pressure as the outside air. Ordinarily closed, it is opened in connection with movements of swallowing. If one has gone down in a rapid elevator from the top of a very high building, one will feel a pressure on the drum. This will be relieved by swallowing.

The Cochlea. — The inner ear, or labyrinth, is filled with lymph. It has two openings into the middle ear, both closed by delicate membranes. One we have mentioned as receiving the foot of the stirrup. The joint is made watertight by a membrane. This is the oval window. The other, a little below the oval window, is closed by a single membrane.

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[1] V D means double or complete vibrations.

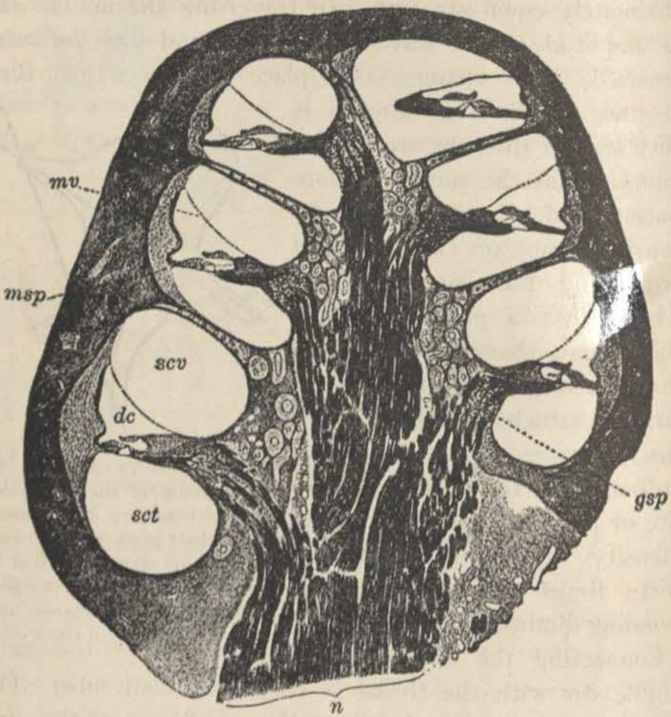

FIG. 58. — Longitudinal section of the cochlea of a cat. *dc*, cochlear duct; *gsp*, spiral ganglion; *msp*, membrana spiralis (basilar membrane); *mv*, Reissner's membrane; *n*, cochlear nerve; *sct*, scala tympani; *scv*, scala vestibuli. (From Huber, after Sobotta.)

From its shape it is called the round window. We may distinguish two parts of the inner ear, the cochlea and the labyrinth proper, — the semicircular canals, utriculus, and sacculus. As the *cochlea* alone is concerned in hearing, we need consider only that now.

In essentials the cochlea is a tube, some four centimeters long wound two and a half times about a central column, the *modiclus*. The cochlear tube is divided into two parts by a spiral ridge of bone, the *lamina spiralis*, which extends from the modiolus and by a membrane which bridges the gap between the end of the ridge and the other wall of the tube. The membrane is known as the *basilar membrane*. Of the two divisions, known as scala or stair cases, the upper or scala vestibuli is continuous to the vestibule which receives the vibrations from the oval window; the lower, or scala tympani, extends downward to the round window.

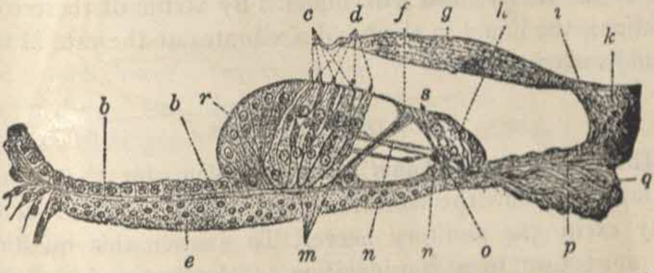

Fig. 59. — Organ of Corti. *b*, basilar membrane; *d*, outer auditory or hair cells; *s*, inner auditory cell; *f*, top of outer rod of Corti, forming one side of the arch of Corti; *o*, inner pillar cell; *g*, tectorial membrane; *q*, nerve fibers; *n*, nerve fibers extending across the canal of Corti. (From Huber, after Retzius.)

The cochlear nerve, the nerve of hearing, enters the center of the modiolus, and ascends to the top, giving off a spiral band of nerves from the bottom to the top of the cochlea. The nerve fibers of this sheet enter the cochlear tube through the spiral ridge of bone, the lamina spiralis, and end in close connection with cells tipped with hairs on the basilar membrane. If one looks at a section of the cochlea, one sees five or six sections of the tube (Fig. 58). In each of these there are three divisions. The upper is the scala vestibuli. A small triangular canal is divided off by the basilar membrane and a delicate membrane above it, Reissner's membrane. This is the cochlear canal. Below the basilar membrane is the scala tympani, which connects with the round window. The vibrations of the stirrup are transmitted to the lymph through the oval window, and ascend to the top of the cochlea by the scala vestibuli. At the apex is an opening between the scala vestibuli and the scala tympani, which is supposed to permit the vibrations to pass from one to the other. The delicate membrane of the round window permits the liquid to vibrate as it could not were there but one opening to the cavity filled with liquid. By virtue of these connections, the liquid in the cochlea vibrates at the rate of the sound wave in the air.

Sensations of Tone

The Qualities of Tone. — The problem for the theory of hearing is how the vibrations in this liquid in the cochlea may excite the auditory nerve. To answer this question we must turn to a consideration of the facts of auditory sensation. Tones vary in three ways: in *pitch*, which corresponds to the rate of vibration of the sounding body and of the air; in *intensity*, which corresponds to the amplitude of vibration, and in *timbre*, which corresponds to the complexity of the tone, to the overtones that are present in addition to the principal tone, or fundamental. The pitch of a tone varies directly with the rate of vibration. The human ear can detect tones only within a limited range. Recent results show that the lowest tone that can be heard varies from about twelve to twenty per second. The upper limit is from eighteen to twenty-two thousand V D. The lowest tones that can be heard are determined by stimulating the ear with large forks. The upper range was first measured by Galton with a whistle of very short barrel. Recently an adaptation of the radio transmitting apparatus has been found to give very accurate results.

The accuracy with which the pitch of tones may be distinguished varies markedly with the absolute pitch. Tones in the middle range can be discriminated much more easily than very high tones or very low tones. From 64 to 1024 V D, one can distinguish differences as small as 0.3–0.2 of a vibration. Above or below this, tones must be much more different to be distinguished. At 32 and 2048 V D the addition of 0.4 of a vibration can just be noticed, and for very high and very low tones, many vibrations may be added before a difference is noted. One can distinguish tones differing by these amounts and even say which is higher and which lower. On the basis of these experiments by Preyer, Luft,[1] and Max Meyer [2] it has been estimated that one can distinguish approximately 11,000 different pitches. Only one or two whole vibrations are needed to make appreciation of the pitch of a note possible. More are needed with the very high tones than with the low.

The Octave as Qualitative Unit. — Within the long series of pitch qualities, the musically trained person recognizes immediately distinguishable fixed points of reference. These fixed points are first the octaves and then the more prominent notes within the octave. For the musically trained at least, octaves resemble each other more than do tones less than an octave apart. Musicians are more likely to mistake notes an octave apart than they are notes within the octave. Within the octave, notes composing the fifth, the fourth and the major third form similar points of reference that are distinguished at once. Possibly this may be due to the use these intervals have in music, but the opinion of trained observers is almost unanimous in favor of regarding them as innate.

Tone-Color. — Two other differences in the quality of tones may be mentioned. One, that tones of the same pitch from different instruments have a characteristic difference ordinarily spoken of as timbre or tone-color, which depends upon the overtones that are added to the fundamental. Thus in the C of 64 double vibrations from a piano string there are also found the c of 128, the g of 192, the c′ of 256, the e′ of 320, the g′ of 384, the seventh overtone of 448 which does not correspond exactly with any note in the scale, the c″ of 512, etc. Every multiple of the rate of vibration of the fundamental is represented, theoretically, since they correspond to the nodes in which the sounding body vibrates, and these nodes are formed at each small fraction of the length of the surrounding body. The first ten overtones can be readily heard when intensified by resonators. If one will hold down a key on the piano that corresponds to one of the overtones, one can hear that overtone continue to vibrate after the fundamental has been dampened by dropping the key. It is started into vibration by resonance and continues to vibrate for a time after its excitant has stopped. With practice one can hear the overtones separately with the unaided ear. Each instrument has its own arrangement of overtones, and these give it its timbre. The tuning fork has almost none; in the piano they are present in fairly even strength, while in the violin certain of the high ones are emphasized at the expense of the lower. Each of the musical instruments owes its peculiar quality to the number, pitch, and relative strength of its overtones.

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[1] *Philosophische Studien*, vol. 4, pp. 511 ff.

[2] *Zeitschr. f. Psychol. u. Phys. d. Sinnesorg.*, vol. 16, pp. 352 ff.

Vowel Qualities. — The difference between vowels spoken or sung at the same pitch is similarly due to a difference in overtones or added qualities. Helmholtz believed that the pitch of the vowel was due to the vibration of the vocal cords or lips. The characteristic difference between two vowels was made by emphasizing certain of the overtones that were present in the vibration of the vocal lips by changing the resonance of the mouth cavity. That the mouth cavity is important is proven by the fact that when a man has had the larynx destroyed and must breathe through an opening in the throat, his voice can be restored by an artificial larynx. A tube is inserted into the opening, and in the tube is a rubber band to replace the vocal cords. A second tube leads from the first to the mouth. By changing the shape of the mouth to produce different resonators, the patient can speak and produce vowel tones which are easily recognized. That vowels and some of the consonants differ in their composition is an accepted fact. How this difference is produced is not a matter of agreement. Hermann and Köhler thought they were produced by the passage of the air through the mouth in much the same way that a bottle can be made to produce a tone by blowing across it. Miller and Gemelli have independently given evidence that vowels may be produced in part at least by interference effects in the larynx itself.

Exactly what components are characteristic for the different vowels is gradually being determined. Köhler found that individuals agreed that a certain note was similar in quality to each of the vowels. These characteristic notes are about an octave apart through the scale. In order he gives the following notes as the characteristic tones of vowel sounds: $m = 130$, $u = 260$, $o = 520$, $a = 1040$, $e = 2080$, $i = 4100$, $s = 8200$, $f = 17{,}000$, $ch = 34{,}000$. All the values are approximate only and the sounds are the sounds of the German letters. Between the pure vowels are mixed ones. One shades gradually over into the other and both elements can be distinguished. While there is probably a regular increase in the pitch of the characteristic tones of the vowels that corresponds roughly to Köhler's results, later workers using various subjective and objective methods find that there are usually not one but several partials or formants that characterize each vowel. The characteristic tones, too, are apparently not single but groups or bands of tones. They can be seen typically in Figure 60 from Fletcher. Von Hornbostel, in the spirit of the Gestalt school, asserts that they vary with

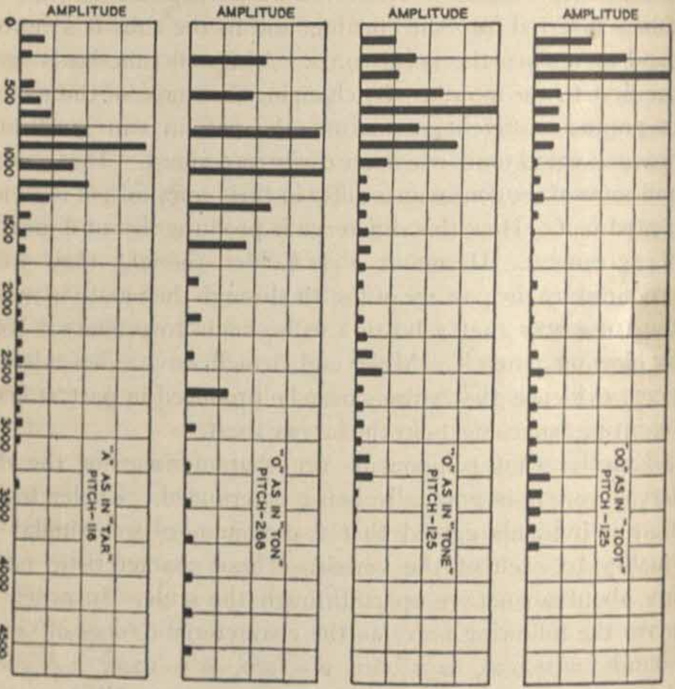

FIG. 60. — Shows the varying components of different vowels. The pitch of the fundamental is given under the sound in the upper right portion of each graph. The black bars indicate the pitch of the different components by their position on the scale. The numbers at the bottom give the vibrations per second of each. The height of the bar shows the relative strength of each component. (From Fletcher's "Speech and Hearing," by permission of D. Van Nostrand Company, publisher.)

the fundamental tone and with many other characteristics of the setting or 'Gestalt.'

Beats. — An effect of combinations that is purely sensational is found in the beat. If two tones of approximately the same pitch are sounded together, there is heard an alternate increase and decrease of the tone which comes as many times a second as the difference in the number of vibrations per second of the component tones. Physically this is due to the fact that the component tones will be alternately in the same phase and in opposite phases. When they are in the same phase, the resultant will be the sum; when in opposite phases, the difference in vibration rate of the two. When these alternations come some distance apart, they are heard as distinct swellings and diminutions; when closer together, merely as a roughness of the tone. For the theory it is interesting to note that most beats seem to be carried by neither of the tones themselves, but by a tone intermediate between the tones that produce the beats. This we must come back to later.

Tonal Fusion. — Of the various phenomena that were mentioned in connection with vision, some are also to be noticed in sound. The phenomenon of mixture of colors is replaced by fusion of tones. The fusions of tones are not readily to be compared with the mixture of colors since the result of the combination of tones is dependent upon the position of the notes within the octave. Each note in a fusion can with a little practice be heard separately; there is no fusion that gives an intermediate tone as in color, and no cancellation, no phenomenon allied to complementariness. The degree of fusion of the whole depends in large measure upon the ratio of vibration rates of the two tones; the smaller the numbers that represent the ratios, the closer the fusion. The best fusion is furnished by the octave, whose components give a vibration rate of 1 : 2, the fifth, 2 : 3, and decreases with the ratios

RATES OF VIBRATION OF TONES IN THE OCTAVE OF MIDDLE C AND RATIO OF VIBRATION RATES OF EACH NOTE TO C

Name of Note . . .	C	D	E♭	E	F	G	A♭	A	B	c
Vibration Rate . . .	264	297	316⅘	330	352	396	422⅖	440	495	528
Ratio of C to Note . .	1 : 1	8 : 9	5 : 6	4 : 5	3 : 4	2 : 3	5 : 8	3 : 5	8 : 15	1 : 2

represented by larger numbers as the second, 8 : 9; the seventh, 8 : 15, etc. The relation holds at least approximately, although critics have insisted that the degree of fusion in certain combinations does not correspond accurately to the smallness of the numbers that express the ratio of vibration rates. Closely related to fusion is consonance or the availability of the combinations for musical effects. This depends partly upon the degree of fusion, more upon the training of the hearer. This dependence upon training is shown by the difference in what is regarded as pleasant between occidental and oriental music and in the gradual change in the accepted intervals in western music. The tritone, the fourth, and the fifth, the only intervals used by the Greeks, have gradually given way to the thirds and sixths, and now we see seconds and sevenths admitted to music under certain circumstances. It is the feeling tone, as well as the physical combinations, that determines the effect.

Helmholtz Theory of Consonance. — An explanation of consonance is given by Helmholtz on the basis of beats. The notes that give the most perfect fusion are themselves far enough apart not to beat and, furthermore, do not give rise to beats between their overtones. Thus the fifth with a ratio of vibrations of 2 : 3 would have as overtones of the first components 4, 6, 8, 10, etc., and as overtones of the second component 6, 9, 12, etc. Of the first four overtones only the 8 and 9, 9 and 10 would be near enough to beat or be dissonant, and two of the first four would be identical, the others no less consonant than the fundamentals themselves. On the other hand, the major seventh, with a ratio of 8 : 15, while giving no beats between the fundamentals, would have beats between most of the overtones. The fundamental of the higher, 15, would beat with the first overtone of the second, 16, the third overtone of the lower beats with the first of the higher, and in general there are many beating overtones and no identical ones below the eighth of one and the fifteenth of the other. In sum, then, dissonant chords may have beats either between the fundamentals or the overtones, while consonant chords have few beats if any between either fundamentals or overtones.

In definite opposition to the Helmholtz theory based on the use of isolated sensations is the Stumpf explanation that certain tones have a common or unitary appeal to the nervous system, what he called *specific synergy*. Von Hornbostle has recently extended this idea in harmony with the Gestalt notion that all depends upon the whole rather than upon the elements. He argues that consonance is an expression of the reaction towards a total situation, that consonance is a response to tone combinations. While that response is approximately constant to the same intervals through the history of western music, still it does vary from age to age with changing experience. The tendency is always to the recognition of new harmonies rather than towards the rejection of the old.

After-Sensations. — Like colors, tones have after-sensations, but only positive ones. It requires some time for a tone to reach its maximum, and also it persists some little time after the physical excitation ceases. The ear is much more rapid in its adaptations than the eye, however; it has much less inertia. According to Mayer separate tones can be heard if they are repeated as frequently as 27 per second for notes of 64 V D and 204 times per second for a note of 1024. There are also intermittent after-sensations of tones, but they are not so often noticed as after-images. Urbantschisch reports that single primary after-tones may last from one to ten seconds. The intermittent after-images may follow each other at irregular intervals for one to two minutes. Each after-sensation will last from 10 to 15 seconds at intervals of from 10 to 20 seconds. Usually these intermittent tones are of the same pitch as the objective tone, but some may be higher or lower. They are fainter than the original and usually fluctuate in intensity.

Corresponding to color blindness are rare cases of what are called tone islands. The patients in this condition are deaf to large portions of the scale but can hear notes of intermediate pitch. More frequent are individuals whose range of audition is shortened above and below, and it is a fairly general rule that the upper notes gradually cease to be heard as a person grows old.

Combination Tones. — An interesting phenomenon of hearing is furnished by combination tones. When two notes are sounded, one frequently hears, in addition to the notes themselves, tones that correspond to the difference between their vibration rates or to the sum of their vibration rates. Thus if the tones c and e of 128 and 160 V D be sounded together, one will hear a note corresponding to the difference in their vibration rates, 32 V D. One can also hear a second difference tone whose rate is the difference in rate between the higher and twice the lower (2 l — h) of 96 V D and a third tone (3 l — 2 h) of 64 V D. Some authorities report that they hear fourth and fifth difference tones named on the analogy of the last. The first and second difference tones are very much more readily heard than any of the others. Only pairs of tones that lie within the octave give rise to difference tones. The explanation is still in some dispute. It has been held that the tones are of purely subjective origin, although recently it has been shown that they are produced in telephone plates. Helmholtz' explanation was that they arose when there was a resistance of the sounding body to vibration in one direction. This was present in the ear since the small bones would give an unsymmetrical loading of the ear drum. The same condition is present in the telephone plate for which the magnetic field produces an unsymmetrical loading. Another combination tone is the summation tone. This is a note that corresponds to the sum of the vibration rates of the component tones. It is not so easy to hear as the difference tones, and it is more difficult to obtain pure conditions for it, as in many cases it will correspond to an overtone or to a difference tone between the overtones. The summation tones are probably of subjective origin, but no satisfactory explanation has been given of how they originate.

Tone and Noise. — A fundamental difference in sounds is that which obtains between tones and noise. The difference is sufficiently familiar to need no description. Physically as well as psychologically two forms of noise are to be distinguished. The more usual is due to a very complex mass of tones that have no simple relation in their vibration rates, and have even been said to be nonpendular in character. Any inharmonious combination of many tones is accepted as noise. A noise of this kind passes gradually over into tone, as the degree of dissonance is lessened, or the tonal element comes to predominate. If there are any tones that are not reducible to the ordinary pendular or sine form, they may also be present in noise. That complex sounds like the sawing of wood or the rattle on a city street are merely tones in great number and variety without any harmonic relation is probable, since with resonators one can distinguish tonal elements in them. The second type of noise corresponds to a simple vibration too short to produce the full tonal character. Upon cutting off a pure tone before it has sounded long enough to produce a real tonal character, a shock is heard which lacks the tonal character. This is usually done by passing the tone through a tube which can be opened to permit the sound to pass for a fraction of a second only. As was said one or two full vibrations in the lower octaves and twelve or more in the higher ranges are required to give a true tonal character. If the sound last for less than this, noise, not tone, is heard. Noise and tone, then, are different only in the time of stimulation or in the arrangement or combination of the elementary waves, not in the character of the waves themselves.

Theories of Hearing. — Helmholtz, whose theory still is the basis of discussion, assumed that the prime organ of hearing was the basilar membrane. He thought of the basilar membrane as composed of a series of fibers tightly stretched that were tuned to respond to all vibration rates that can be heard. As a tone was struck, it passed through the air to the drum, and excited the drum and ossicles of the middle ear to vibrate. The vibrations were transmitted to the liquid of the inner ear by the foot of the stirrup and by resonance evoked vibrations in all of the fibers of the basilar membrane that were tuned to any one of the components. It was much like the vibrations of the strings of a piano induced if one speaks near it.

The plausibility of the theory depends much upon the characteristics of the membrane and its connections with the nerve. The basilar membrane does contain numerous fine transverse fibers embedded in other tissues. They vary in length with the longest hairs at the top of the cochlea, the shortest near the bottom. Claudius recently found the length for one individual to be 128 μ for the shortest and 234 μ for the longest, in another the shortest was 176 μ, the longest 480 μ. These differences in length are not sufficient to explain the tuning for one to 16 vibrations and of the other to 20,000. It is assumed that part of the tuning depends upon the loading of the strings. They are sufficiently numerous, 24,000 according to Claudius, to provide one for each tone, although the revisions of the Helmholtz theory assume that the membrane vibrates in bands and not by single fibers.

This would make the exact number of separate fibers relatively unimportant. The fibers of the nerve of hearing end not in the basilar membrane itself but in a series of rows of hair cells that rest upon it. According to the theory the membrane is set into vibration and this vibration affects the hair cells and through them the auditory nerve is stimulated. The details of these relations can be made out in Figure 59. Two other structures that are prominent in the diagram are the rods of Corti and the tectorial membrane. The rods of Corti are based on the basilar membrane, and bend towards each other to be jointed together at the top. The tectorial membrane extends over the whole series of structures from a point of attachment on the lamina spiralis. The rods of Corti are not given a function by any of the theories. Helmholtz made the tectorial membrane a dampener to stop the vibration of the membrane when the tones ceased. Hardesty and Shambaugh regard it as the real resonator.

Details of the Helmholtz Theory. — The theory is adapted to explain a number of the facts of hearing. Beats may be regarded as due to an overlapping of the vibrating portions of the membrane, and thus as giving rise to an interference phenomenon in the intermediate fibers. On this assumption each tone would cause a ribbon of several fibers to vibrate instead of a single fiber as Helmholtz first asserted. When they were near together, the outer edges of the two ribbons would have common fibers. These would tend to vibrate with the rates of both notes, and the interference of the two movements would cause the beats. This view receives support from the fact mentioned earlier that it is a note intermediate between the other two that beats rather than either of the component tones.[1] It is the intermediate fibers that are vibrating at two different rates and consequently carry the beats. When the vibrating ribbons are sufficiently far apart there are no interferences and so no beats. It is assumed that each note in a compound tone stimulates a single fiber or small band of the basilar membrane. The effects of these stimulations are carried over separate nerves to the auditory cortex and there in some way all unite again to produce the compound tone.

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[1] Marguerite Eberhardt. *Psychologische Forschungen*, vol. ii, pp. 336–345.

The Pros and Cons of the Helmholtz Theory. — On the whole the Helmholtz theory has more adherents at present than any other. The strongest arguments against it are the improbability that the basilar membrane could respond to the separate tones, and the lack of directness in the connection between the basilar membrane and the hair cells about which the nerves of hearing end. As opposed to this there seems to be definite evidence that injury to separate parts of the basilar membrane produces deafness for particular tones that would roughly correspond to the area injured. Occasionally an individual is found who cannot hear a limited range of pitches. Post mortem examination shows the deterioration of limited ranges of the basilar membrane. Held succeeded in drilling a small hole in the basilar membrane of a guinea pig. Using the ear reflex as an indication of hearing he found that the guinea pig was then deaf to a limited number of tones. Numerous experiments show that keeping an animal for a long time near a loud tone produces a degeneration in a definite part of the basilar membrane. These results all speak strongly in favor of a resonance theory, whatever tissues be the medium of the resonance.

Telephone Theories. — Other theories abandon the resonator principle, assuming instead that some structure in the cochlea must vibrate as a whole, and the analysis of the separate tones be made by the cortical centers. Waller and Rutherford have assumed that the basilar membrane, acting much like the plate of a telephone, transmits the complex notes to the cortex where analysis takes place. Max

Meyer has a somewhat similar theory. His assumption is that the intensity of the tone is determined by the distance the vibration extends inward from the oval window, while the quality is determined by the rate of vibration of the membrane as a whole. The difficulty with this whole group of theories lies in the assumption that differences in vibration rate so slight as one in ten thousand should be appreciated by the cortex, while the most delicate appreciation of differences in intensities is one in a hundred. The difference in intensity that can be appreciated by the ear is only one in five.

An ingenious experiment by Wever and Bray now considered would have a definite bearing upon the telephone theory. The auditory nerve of a living cat was connected with an oscillograph that recorded the currents of action. It was found that when a sound was presented to the ear, electrical waves corresponding exactly to the sounds presented were recorded. So detailed was the resemblance that a telephone in a distant room connected with the auditory nerve gave the voice of a man speaking into the ear of the cat so clearly that the man's voice could be recognized. An advocate of the telephone theory might easily argue that if the nerve carries oscillations that correspond so closely to those in the external air there is no difficulty in assuming the analysis required by the telephone theory. The authors themselves did not draw this conclusion. On the contrary they assumed that a resonance was responsible for the analysis and that the effects were recombined in the nerve currents.

Whether the results themselves are to be accepted is still open to question. One repetition of the experiment confirmed the results. Several others failed. The people who failed argued that some unsuspected microphone had been accidentally introduced into the circuit. In general, it has been found that the oscillation of currents of action was not more than

150 per second, while these oscillations were at the rate of several thousand per second.

A modification of the resonance theory was suggested by Hardesty and accepted by Shambaugh. Hardesty[1] has abandoned the basilar membrane as the vibrating mechanism and assumes that the tectorial membrane is the receiving organ. Hardesty argues that the vibrations of the liquid are taken up by the tectorial membrane and communicated to the hair cells and thence carried to the brain, where, as in the other theories of this type, analysis takes place.

While there are still many problems to be solved before a complete confirmation of a theory is possible, there is a strong trend in the authorities to accept some form of a resonance explanation of hearing. At different times strong objections have been raised to the Helmholtz theory, but at present many hold to it in almost the original form.

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TACTUAL SENSATIONS

Cutaneous Sensations. — The sensations from the skin are simplest of all, and their organs are most accessible, but only in the present generation have the more important facts concerning them been discovered. The same distinctions between physical stimulus, physiological processes, and sensations, that have been made in connection with the other senses, are to be drawn here. The adequate stimuli for the skin are mechanical and thermal. But while the stimuli vary only in intensity, different sense organs are affected by different intensities, and corresponding differences in sensation result. This is most marked in the temperature sense. The physicist assures us that cold is nothing positive, but merely a reduction in the amount of heat. Nevertheless when the temperature is reduced much below 30° C. a sense organ is excited which gives rise to the sensation of cold, and this sensation increases as the temperature is lowered. Above 30° another organ is stimulated to excite the sensation of warmth and its activity increases as the temperature rises. Similarly, slight mechanical stimuli excite sensations of pressure; and intense ones, sensations of pain. We then have four distinct sense qualities, while there are but two kinds of physical stimulus. More clearly than in any other organ can the sense qualities be shown to depend upon the organ stimulated.

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[1] "On the Nature of the Tectorial Membrane," etc., *Amer. Journ. of Anatomy*, vol. viii, p. 109.

TEMPERATURE

The discovery of the distribution of the organs, and with that the settlement of most of the problems of cutaneous sensibility, is a matter of comparatively recent date. It came first in the temperature senses. At approximately the same time and altogether independently of each other three investigators, Blix, a Scandinavian (1882), Goldscheider, a German, and Donaldson, an American (both 1885), found that the skin was sensitive to temperature only in relatively isolated spots rather than all over, as had been earlier supposed. The skin was carefully tested point by point with a cooled or heated metal point, and it was found that at certain points irregularly arranged one would feel cold, at others, warmth. The most important disagreement in the results found was between Goldscheider on the one side and Blix, with practically all later workers, on the other. Goldscheider found warm and cold points to be thickly scattered everywhere on the skin; for example, on the back of the hand there were

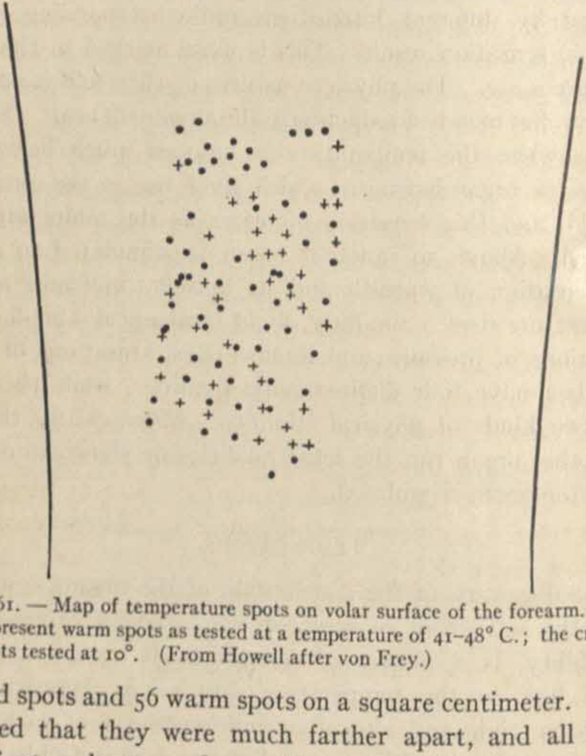

FIG. 61. — Map of temperature spots on volar surface of the forearm. The dots represent warm spots as tested at a temperature of 41–48° C.; the crosses, cold spots tested at 10°. (From Howell after von Frey.)

68 cold spots and 56 warm spots on a square centimeter. Blix reported that they were much farther apart, and all later investigators have confirmed his results. Sommer counted carefully the number in many square centimeters and found that there were from 6 to 24 cold spots, and from 0 to 3 warm spots, to the square centimeter. He gave as his average 12 to 13 cold and 1 to 2 warm spots. His estimate for the whole body was 250,000 cold and 30,000 warm spots.

Indirect Evidence of the Existence of Warm and Cold Spots. — Many of the earlier theories assumed that there must be a single organ for warmth and cold. Hering, for example, had a theory which would make warm and cold depend upon assimilation and dissimilation in the single organ, in very much the same way that his complementary colors depended upon those processes in the single color organ. It was therefore essential when the spots were first mapped to prove by other evidence that the spots were distinct. Certain characteristic differences in the way the two organs respond and in the substances that stimulate them provided this evidence. (1) It takes considerably longer to stimulate the warm spots than the cold spots, perhaps an evidence that the former are farther from the surface. (2) Certain inadequate stimuli will affect one but not the other. Cold is particularly easy to excite by induction currents, by pressure, or even by heat. Menthol stimulates the cold, carbon dioxide the warm organs. (3) There are certain larger areas of the body in which only one sort of sensation will be found. Thus on the cornea and conjunctiva of the eye cold alone is felt, warmth is lacking altogether. That there are different organs for cold and for warmth is not now disputed.

The Temperature Scale. — The more detailed relation between the physical temperature and the sensations that result from the stimulation may be given. The critical point for most purposes is the so-called physiological zero point that separates cold from warm. The point varies much with the temperature to which the skin has been adapted. For a covered part of the body, it is apparently in the neighborhood of from 28° to 30° C.; on the back of the hand, it has been found to vary between 23° and 33°, and after the hand has been immersed in water at 11° for some time, water at 12° seems warm, and it may similarly be adapted for temperatures of 39°. The width of the indifference point is seldom greater than 0.5°. If we assume an indifference point at 30° C., below it the cold spots alone are stimulated to somewhere in the neighborhood of 10°, where pain is added to the complex. Above, one obtains warmth alone up to 45°. Here the cold spots are excited in addition to the warmth,

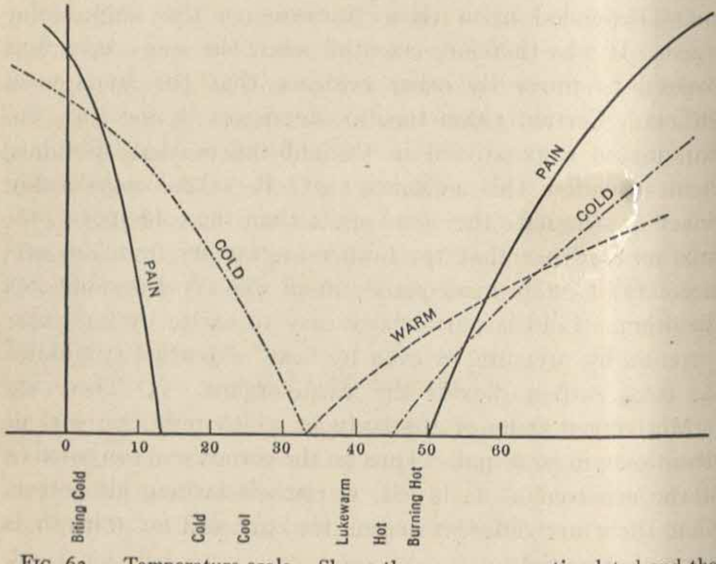

FIG. 62. — Temperature scale. Shows the sense organs stimulated and the degree of stimulation at different temperatures. Figures on the base line indicate the temperature in centigrade, the height, the degree of stimulation. (After von Frey.)

and the combination gives hot as opposed to lukewarm. This excitation of the cold organ by a hot stimulus gives what is known as a paradoxical cold. The fact was first discovered by Alrutz and has been confirmed by von Frey. One experiment performed by Alrutz was to fatigue the warm spots in the foot by keeping it immersed for some time in warm water and then to swing it quickly through hot water. The hot water then seemed cold. Above 50° to 55° the sensation of burning heat makes its appearance as a consequence of the mixture of pain with the other sensations. The question naturally arose as to whether there was a paradoxical warmth at the lower ranges similar to the paradoxical cold. The burning sensation after long exposure to cold suggests that the warm spots might be stimulated. Goldscheider and others reported that heat could be noted as a consequence of stimulating warm spots by cold objects. Alrutz, Thunberg, and others could not confirm his results, but he still holds to his opinion although he admits that they are much less obvious than the paradoxical cold sensations. Jenkins has recently obtained results which would confirm Goldscheider. The warm or hot sensations noticed after exposure to cold may be due to the mixture of sensations of pain with tinglings due to changes in circulation. Figure 62 shows these various phenomena in diagrammatic form.

PRESSURE AND PAIN

Mechanical Cutaneous Sensations. — Very much the same distinction may be made between pressure and pain as between warmth and cold. Goldscheider also discovered that certain points only on the body would respond to pressure. There was approximately the same difference of opinion between Goldscheider and the others as to the number of spots. Goldscheider found many, the others relatively few. Von Frey, who has done the most careful and most recent work on the pressure sensations, found that there are from 0 to 300 per square centimeter. On the whole body surface, excluding the head where they are the most numerous, he estimates there are approximately 500,000. They are more numerous than either kind of temperature spots. In determining their position von Frey used fine hairs mounted on matches or similar small bits of wood. These gave a very small point and a constant pressure. Wherever there were hairs on the body he found that the pressure spots correspond to them. They are also found on the surfaces free from hairs.

Sensations of Pain. — Pain has been even more in dispute than the other senses. Until von Frey's[1] work in 1896 it had usually been held either that pain was a feeling, not a sensation at all, or, if it was a sensation, that it must be regarded as due merely to the overstimulation of the pressure organ. Goldscheider in his investigations modified this view slightly. Pain stimuli were carried to the spinal cord by the same neurones as pressure, but there took a different course. While the pressure sensation continued by the same neurone up the posterior columns, the intense impressions were supposed to force a way across a synapse to new neurones with cells in the central gray and take another path. As evidence that there is this more difficult path through the central gray, Goldscheider adduces the long time required to receive pain sensations. The reaction time for pressure is from 0.12 to 0.2, while the time for pain rises to 0.6 to 0.8 second. He uses this theory also to explain summation pains such as those involved in the Chinese water torture, in which drops of water are permitted to fall for a long time upon the same point until the successive slight stimuli give rise to an unbearable pain. The summation is assumed to take place in the cells of the cord. Also the effects in the disease syringomyelia are mentioned as confirmatory of his theory. In this disease an infection extends from the central canal, destroying the cells in the surrounding gray matter. Patients suffering from this disease feel only pressure and cold in certain areas of the skin, but have no sensations of pain and warmth. Goldscheider interpreted this to mean that the paths for pain were destroyed, while the paths through the white matter were left intact. Anatomical findings have since confirmed the presence of the separate paths for pain and pressure sensations, although in his latest discussions Goldscheider[1] himself does not specifically reaffirm his theory that there is a separation between pain and pressure only when the cord is reached.

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[1] *Leipziger Abhandlung*, 1896.

Referred Pains. — Goldscheider, too, explained on this theory the 'referred pains' so prominent in most diseases. He assumes that two or more regions of the body are connected with the same cells in the cord. Thus he would say that the mucous membrane of the stomach and the skin of the back were connected with the same cells in the cord. When certain disturbances of the stomach developed, the excitation of its nerves would be carried to the cells in the cord which give rise to the sensation of pain, and the sensation would be excited in the cortex. But since the same cells also transmit pain impulses from the middle of the back, and we are much more familiar with that area, the pain would be referred to the known region, the back, rather than to the wall of the stomach, a surface never seen and where voluntary contact has never produced pains. A somewhat similar theory of referred pains has been given by Head[2] without accepting the other portions of Goldscheider's theory.

Pain Spots. — More recent investigations have shown that the first part of Goldscheider's theory, that pain and pressure impulses have the same path to the cord, is probably incorrect. Von Frey, in particular, by very careful mapping of the skin, has shown that there are special pain spots in the skin in addition to the pressure and temperature spots. The mapping was on an enlarged scale diagram of the small portion of the skin worked with. The skin was explored with a sharpened horse hair under a magnifying glass, and it was found that sensations of pain arose only at certain points, mostly in the small lines of depression on the skin. These were found to be much less sensitive than the pressure spots, required

[1] *Handbuch der Physiologie, normal und pathologische*, Bd. XI, pp. 192 ff.

[2] *Brain*, 1893.

about one thousand times as great a pressure to stimulate them, and were much more numerous than any other — on the average, one hundred to the square centimeter. It was estimated that there are between two and four million pain spots on the surface of the body. Much corroboratory evidence has been brought to confirm the results of mapping the spots. It has been found that certain parts of the body, the conjunctiva of the eye, for example, are the seat of pain spots but not of pressure spots; others, as the inner lining of the cheek, contain pressure spots but no pain spots. Another bit of evidence depends upon the slow response to pain mentioned above. If a pressure spot be stimulated by a slight alternating electric current with alternations of fifty or sixty per second, the separate alternations will be noticed. If, on the contrary, the current be applied to a pain spot, there is a continuous sharp sensation. Goldscheider still (1929) holds to his theory that pain is in some way related to pressure although he recognizes von Frey's result that pain is aroused in a different spot from that which gives rise to pressure. Goldscheider places his reliance upon his observation that the pain sensation is preceded by a slight non-painful impression. Pain is for him, nevertheless, a real sensation and not a mere feeling accompaniment of intense pressure or other sensation.

Cutaneous Sense Organs. — The sense organs for these different sensations have been investigated, and the results seem to bring out sharp differences between two schools. Von Frey has gone farthest in assigning an organ to each of the cutaneous sensations. We may summarize his conclusions first.

Pressure spots seem closely connected with the hairs on the parts of the body where there are hairs. The spot that responds is always just over the root of a hair (Fig. 63). It is probable that the nerve about the root is stimulated by the hair which, as it is bent, acts as a lever. On the surfaces without hairs, the palms and soles of the feet, von Frey suggests that the Meissner corpuscle (Fig. 64) is the organ. Pain spots are ascribed to the free nerve endings (Fig. 65). These are most numerous and come closest to the surface of any of the end organs in the skin, and the sensations of pain are aroused by the most superficial stimulations. Acids that

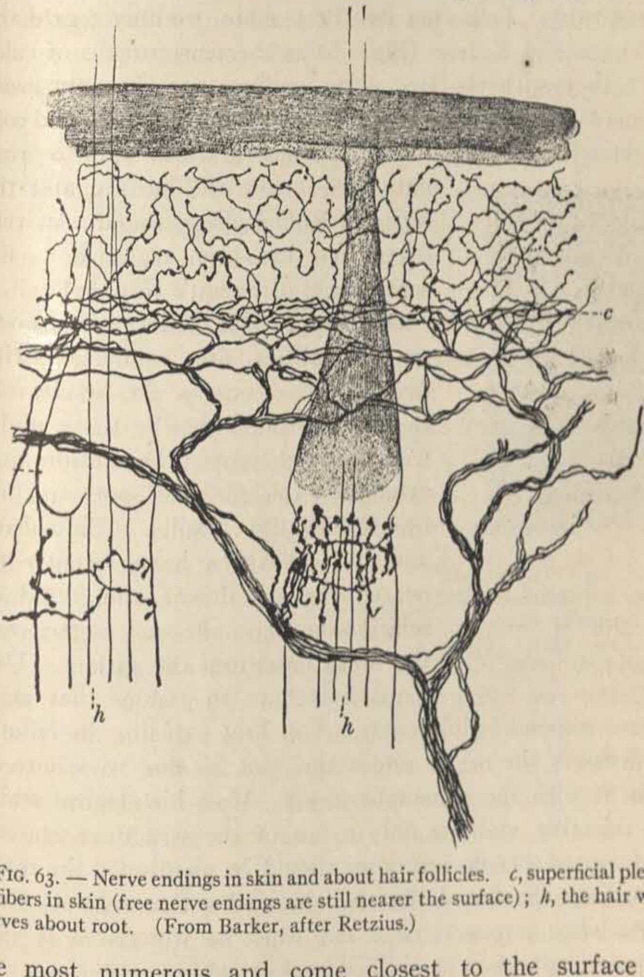

FIG. 63. — Nerve endings in skin and about hair follicles. *c*, superficial plexus of fibers in skin (free nerve endings are still nearer the surface); *h*, the hair with nerves about root. (From Barker, after Retzius.)

affect only the epidermis give pain sensations without sensations of pressure or temperature. It is more difficult to determine the organs for temperature and the results are less trustworthy. Following von Frey again, we may regard the end organs of Krause (Fig. 66) as the sense organs of cold, since they with the free nerve endings are the only sense organs found in the conjunctiva, where also only pain and cold can be felt. Because the sensations of warmth seem to originate well below the surface and the organ of Ruffini also is found relatively deep, that has been regarded as the sense organ of warmth (Fig. 67).

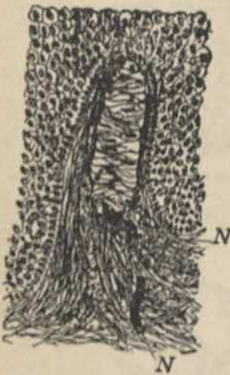

Fig. 64. — Tactile corpuscle of Meissner from the skin of the toe. *N*, nerve fiber. (From Barker.)

Opposed to this belief that specific sense qualities are connected with definite sense organs are results obtained by examining the tissue under well mapped spots. Donaldson first attempted this for cold spots and obtained negative results. Dallenbach and his colleagues have recently repeated the experiment and found no relation between the end organs and the sensations from the surface. Dallenbach inclines to assume that sense organs respond indifferently. Von Frey explains the failures to discover the organ under the spot as due to failure to stain it with the substances used. Most histological stains are selective, staining only a few of the structures present. In favor of specific responses should be mentioned the result of Adrian who found that he obtained action currents from a Pacinian corpuscle of a cat when he stimulated it with pressure, not when he applied heat or cold.

Regeneration of Cutaneous Sensations. — An experiment performed by Head and Rivers tends to establish a second

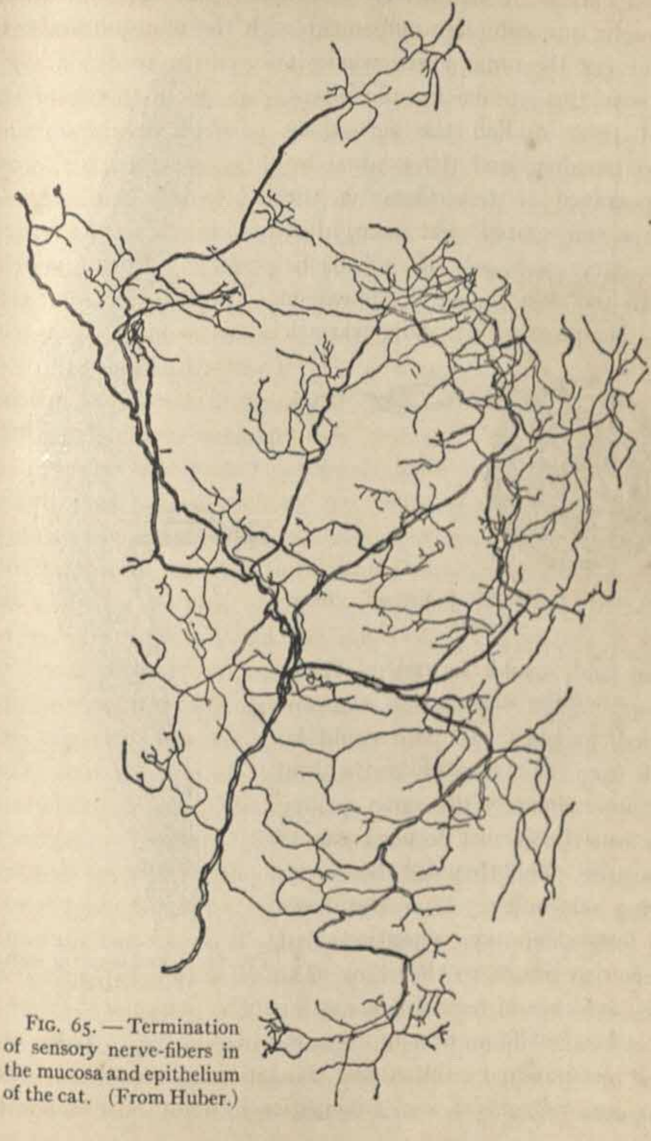

FIG. 65. — Termination of sensory nerve-fibers in the mucosa and epithelium of the cat. (From Huber.)

classification of cutaneous sensations that has not been brought into complete agreement with the one given above. They cut the ulnar nerve where it is near the surface at the elbow and then studied the sensations that remained and the gradual reappearance of sensations as the nerve regenerated. At once, after the nerve was cut, all sensations from the skin proper disappeared. Neither pressure nor pain, warmth nor cold, could be felt. When more intense stimulation was applied, pressure and pain could be felt from the tissues under the skin, of approximately the same quality as from the normal deeper tissue in the arm. This they call the deeper lying sensibility. After the lapse of forty-three days, sensations first began to return to the skin. The first evidence of regaining sensation was in the diminution of the area insensitive to pain. On the one hundred twelfth day sensations of cold made their appearance, and the area sensitive to pain had much in-

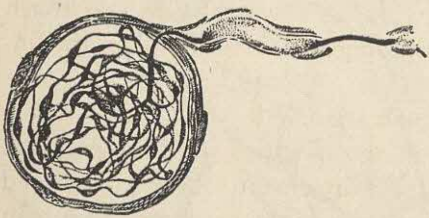

FIG. 66. — End bulb of Krause. (From Barker.)

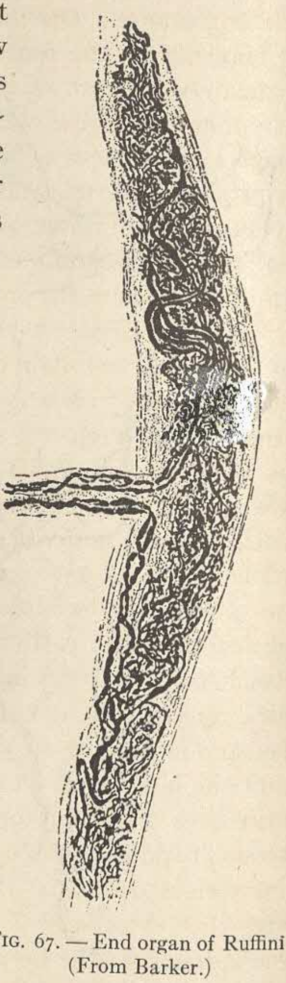

FIG. 67. — End organ of Ruffini (From Barker.)

creased. Nearly two months later the hairs were found to be sensitive to light touch, and a few warm spots made their appearance. One hundred and ninety days after the operation all of the sense qualities had returned over approximately the entire area. But each of the sensations was limited in some way as compared with the normal. Temperatures below 37° C. and above 27° C. could not be felt at all. Pain sensations could be felt only from unusually intense excitations, and then were exceedingly disagreeable and diffuse, and were generally referred to some point at a distance from the one stimulated. Touch could be felt only on the hairs, — when an area was shaved, no touch was felt. The sensibility producing this condition the investigators call *protopathic*.

Curiously enough one small triangle in the affected region was discovered in which all the qualities were present that were lacking from the rest. Temperatures between 27° and 37° C. could be noticed, but none of the extremes. No pain was felt; pricks gave mere sensations of contact and were always correctly localized. Perhaps most remarkable of all, light contact with cotton wool was appreciated on this small triangle from the beginning and was correctly localized whether hairs were or were not stimulated. This more highly developed and more accurate sensibility was known as the *epicritic*. After the lapse of a year, the epicritic sense returned to the entire area. The protopathic sensibility had reappeared in the small triangle with epicritic sensitivity only, one hundred ninety-eight days after the operation. This experiment indicates that three sets of sensory nerves supply any member. One is found in the deep tissues, the two others in the skin. Of the latter one provides the coarser, more intense sensations, the other the more delicate. The protopathic is stimulated only by relatively intense pressure and that only on the hairs; very intense stimuli also give pain. It also is affected by the extremes of temperature alone. The epicritic sense, on the other hand, supplies the gaps left by this sense; it appreciates moderate temperatures and slight pressures. The relation between the separate spots that have been shown to produce the specific sensations and the epicritic and protopathic sensibilities has not been completely worked out. The experiment has been repeated using smaller areas by different workers, especially by Trotter and Davies and by Boring without confirming definitely the division into protopathic and epicritic sense groups. They found a gradual return of each sense quality. Pain, pressure, and cold returned at approximately the same time and warmth considerably later. While the Head and Rivers' results are not generally accepted, they offer an interesting point for discussion. This is especially true, since Head assumes that the protopathic sensations are appreciated by the thalamus and the epicritic by the cortex, and the functions of the thalamus are arousing new attention in connection with theories of emotion.

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SENSATIONS OF TASTE

Gustatory Sensations. — While tactual sensations have been found much more numerous than was thought before accurate scientific investigation began, sensations of taste have been diminished in number quite as definitely and markedly. According to the popular mind today and the scientific opinion of one hundred years ago there are a very large number of taste qualities. Even after experiments had been made, it was generally believed that at least six could be distinguished. The older list included nauseating tastes, aromatic, and other qualities that we now know to be derived from smell. Chevreul showed in 1824 that these must be smell qualities by his discovery that they disappeared upon closing the nostrils. Until relatively recently salt, sweet, sour, bitter, metallic, and alkaline were regarded as the primary tastes. The metallic seems on closer experimentation to be a compound of taste with smell and with mechanical and perhaps muscular sensations. The metallic surface may produce slight muscular contractions in the neighborhood of contact which unite with the other taste and smell sensations to produce a complex. Alkalies if strong may make the tongue slippery and may also produce puckering of the surface of the tongue. Von Frey has shown by closing the nostrils while tasting that alkalies also contain odors. When the tongue is at rest and the nose closed, the only sensation is a slight bitterness. Eliminating all sensations of smell, which furnish a large part of what is called taste in gastronomic relations, and all tactual and tempera-

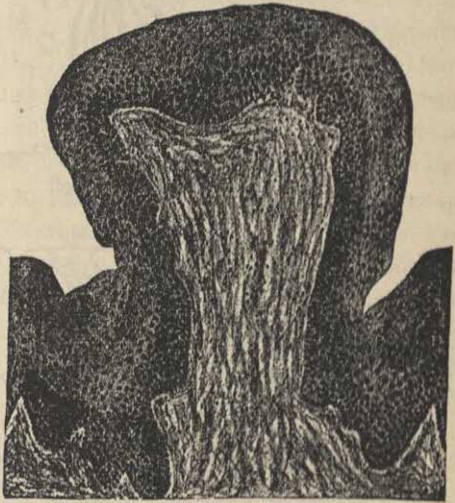

FIG. 68. — Fungiform papilla from human tongue. (From Huber.)

ture sensations, such as the biting of spices, etc., we have left only four true tastes, — sweet, salt, sour, and bitter.

Sense Organs of Taste. — The problem of the organ of taste, and its specific type of reaction, is similar to the same problem on the skin, but slightly more complicated. The sense endings of taste are found primarily upon the tongue, but also in some numbers upon the soft palate, upon the cords of the larynx, the epiglottis, and in children on the inner lining of the cheek. On the tongue the end-organs are the papillæ. These are elevations set deep in the mucosa. The sense ends are on the sides of the resulting folds. The most striking are the circumvallate papillæ, from seven to twelve circular depressions, much like the moat of a walled town, arranged in

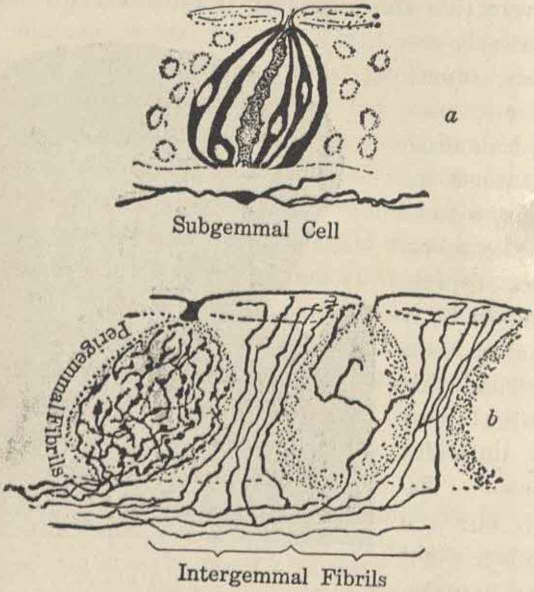

FIG. 69. — Taste buds and endings of gustatory nerve; *a* shows taste cells about a central supporting cell; *b*, fibrils around and between the taste-buds. (From Barker.)

an angle upon the back of the tongue. The most numerous type in man are the fungiform, whose small red openings may be seen upon the tip of the tongue. In some human beings the foliate papillæ are present and have sense organs. They are very prominent in animals. The real sense ending is the *taste bud* or beaker. These are collections of taste cells and supporting cells arranged in the form of a bud. The taste cells have hairs on their ends that extend into the papillæ where they come into contact with the saliva in which the chemical substance that gives rise to the taste has been dissolved. Around the taste cells are nerve fibrils bare of their medullary sheaths. The function of the papillæ is apparently to catch the saliva and permit it to come into contact with the taste cells, and there to start the nervous impulse.

The Organs for Different Tastes. — Much discussion has been devoted to the question whether a single taste bud in a papilla can give rise to one only or to more than one sensation. Experiments performed by Oehrwall of stimulating the papillæ separately showed that more than one sensation might be received through a single papilla. He mapped accurately 125 papillæ and then stimulated each separately with solutions of sugar, quinine, and tartaric acid. Of these, 27 gave no response at all, 60 responded to all three substances, 12 gave acid only, 3 sweet only, none bitter only, 4 gave sweet and bitter, 12 sweet and acid, 7 acid and bitter. From this experiment, which has been repeated by several investigators with approximately the same result, it is evident that the papillæ cannot be regarded as the organs of different special sense qualities as are the spots on the skin. It is suggested by the supporters of the doctrine of specific energies that the immediate sense end is the taste bud and that, as there are always many of these in each papilla, it is possible that each taste corresponds to a particular sort of nerve end, but that several different kinds are found in each papilla. As the separate beakers cannot be stimulated individually, this assumption cannot be confirmed directly.

Indirect Evidence for Specific Organs. — Some indirect evidence in its favor is offered by the fact that on the application of certain drugs the tastes disappear one at a time, presumably due to the fact that the primary end-organs are affected with different ease. Thus, cocaine applied to the tongue destroys first the sensation of bitter, and the others in succession, while gymnemic acid first destroys the sensation sweet. As further evidence that there are specific endings for each quality, the same substance will produce a different taste as it is applied to one part of the tongue or the other: sodium sulphate has a sweet taste on the tip, a bitter taste on the back of the tongue, a difference that must be due to the organ stimulated. Similarly, pressure upon or electrical stimulation of the chorda tympani, one of the nerves of taste, where it passes through the middle ear, may produce sensations of sweet, salt or sour, but not bitter. Still another bit of evidence for the independence of the organs for the different tastes is difference in the time required for stimulation. On the tip of the tongue salt requires from 0.25–0.72 second to be appreciated; sweet, 0.30–0.85; sour, 0.64–0.70; bitter, 1–2 seconds. The longer time for bitter is especially striking. While the doctrine of specific energies is not open to direct test, the indirect evidence, so far as it exists, supports the hypothesis.

Taste Qualities and Chemical Composition. — Attempts have been made to discover some relation between the chemical composition of substances and their tastes. As is well known, acids are sour so generally that the two words are popularly synonymous as applied to taste, and in German are designated by the same word. There are, however, many exceptions on both sides. For the other qualities the lack of relation between the chemical composition and taste is striking. The more familiar sweets are carbohydrates, but lead acetate, salts of the other heavy metals, and even some alkalies have sweet as one of the component tastes. Much the same statement may be made of the bitter substances. Usually they have a complex molecule, and the more complex, the more bitter, but no more accurate law has been developed. The simple salts are usually more or less salt, but there are many exceptions. In general, the attempts to correlate taste and chemical composition have led to no noteworthy results.

Of interest in connection with chemical composition and characteristic taste is the discovery of a complex chemical compound para-ethoxy-phenol-thio-carbamide which is extremely bitter for some individuals and tasteless for others. It is interesting also as showing that there are great differences in the development of taste organs in different individuals.

Taste Fusions and Taste Contrasts. — The taste qualities show some of the interrelations found in vision. Tastes mix with each other, with the cutaneous sensitivities, and with odors to produce complexes that are not readily analyzable. The statements hold less for taste alone than for mixtures with the cutaneous and olfactory senses. It seems that sweet and sour, sweet and bitter, combine in foods to advantage. Salt and sweet have approximately the relation of complementary colors. When mixed in weak solutions, Kiesow found that they nullify each other. Also when applied to neighboring areas of the tongue, they reënforce each other, that is, show contrast effects. Thus if one pour upon one side of the tongue a solution of sugar too weak to be tasted alone, and upon the other a salt solution, the sweet will be noticed. Even distilled water may by the same means be given a sweet taste. Other tastes, as sweet and bitter, applied to opposite sides of the tongue, when intense, may alternate; first one appears, then the other, a process resembling binocular rivalry of colors.

The nerves of taste offer some complication. According to Zander, there are three nerves of taste and one of cutaneous sensibility. Of the true taste nerves, the glossopharyngeal, the ninth, supplies the back portion of the tongue; the vagus supplies the taste buds of the larynx and epiglottis and a small area on the very back of the tongue; while the chorda tympani named because it passes across the middle ear back of the drum carries the sensations from the forward areas. The chorda tympani enters the tongue as a part of the lingualis, the other portion of which is a branch of the trigeminus, and is the nerve of cutaneous sensibility. In its midcourse it is alone, and then enters the brain stem as part of the intermediate nerve.

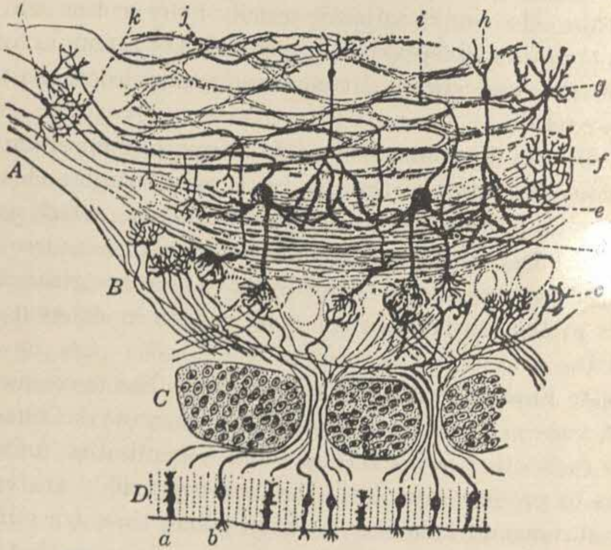

FIG. 70. — Olfactory apparatus. *D*, the olfactory membrane and endings; *B*, glomeruli where end-brush of olfactory neurones connects with dendrite of the more central neurones. (From Barker, after Ramon y Cajal.)

SENSATIONS OF SMELL

Olfactory Sensations. — The organ for smell is situated in a narrow cleft, the olfactory fissure at the very top of the nasal cavity, just under the olfactory lobe at the base of the brain. The olfactory area is marked by a brown pigment which extends over the upper portion of the septum and the roof of the olfactory fissure. The olfactory area is much smaller in man than in animals that make more use of the olfactory sense. The olfactory fissure is above the direct respiratory path — only eddies of the air inspired or expired reach it. This is a protective measure, as dust and other harmful impurities are largely prevented from affecting the endings. The end organ proper is found in the *olfactory cells*, the only true nerve cells which reach the outer surface of the body (Fig. 70). These cells end in hairs that project slightly from the surface. The axones of the cells pass upwards through numerous openings in the skull to make connections in the glomeruli (Fig. 70) with neurones of the olfactory lobe, and thence to connect with the cortical areas for smell. Between the olfactory cells are supporting cells. The chemical substance that gives rise to the odor is carried in the inspired or expired air and comes into direct contact with the hairs of the olfactory cells, where we may assume that the chemical reaction excites the nervous impulse.

Olfactory Qualities. — How many sensations of smell there are is still a moot question. The organ is so situated that no direct experiment may be made upon it, and the indirect experiments either have not been carried far enough or are inaccurate. Aronsohn long ago attempted to determine the number of separate odors by a fatigue method. His theory assumed that one might tire the organ by smelling some one substance, rosewater, for example, until that substance could no longer be detected, and then while the fatigue persisted, test the odors of different substances. Any that could still be detected would belong to some other class, must be sensed through some other organ; those that could not be distinguished would belong to the same class. The method has been proved to be practical, but the large number of substances to be tested and the difficulty in knowing whether the organ is still fatigued for the standard odor have prevented its extensive application. Other evidence of the existence of separate olfactory organs is furnished by pathology. In some diseases of the olfactory region, appreciation of certain odors will be lost while others will still be noticed. But the observations have not been carried far enough to give an accurate classification.

Henning's Olfactory Qualities. — Henning[1] has recently made a classification of odors by questioning men who had special skill in discriminating them. His conclusion is that we may distinguish six primary qualities with a series between each pair that partakes of the qualities of the two extremes. These fundamental odors are the spice odors, flower odors, fruit odors, resinous or balsam odors, foul odors, and burning odors. Instances of the first class are fennel, cloves, sassafras oil. Included in the flower or fragrant odors are heliotrope, oil of jasmin, and oil of geranium. The fruit odors include the fruits proper, oil of citronella, and ethyl ether. The resinous or balsam combinations include turpentine, oil of eucalyptus and oil of cedar, as well as the true resins. The foul odors are typified by hydrogen sulphide and other sulphur compounds in addition to bad cheese and similar disagreeable odors of organic origin. The burning odors are typified by smoke, minus the burning sensation, pyridin, and tar.

Henning's Olfactory Prism. — Henning arranges these odors on a prism with the primary odors at the corners and the intermediate ones on the lines joining them. Typical intermediates between fruit and foul are dill, leek, celery, onion, oil of mustard, and foul cheese; between the burning and spicy lies browning coffee; between burning and resinous, burning varnish. The primary odors of Henning correspond very closely with many of the older classifications. The principal difference is that he omits a number included by the older men which are compounds of smell with pain and other senses. His results can be readily tested and on the whole confirmed. Henning's list of odors probably represents a minimum number of olfactory qualities, and many authorities think that it will probably need several additions. It does represent a typical modern opinion as to the number and possible interrelations of primary odors.

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[1] H. Henning, *Der Geruch*, 1924, Leipzig.

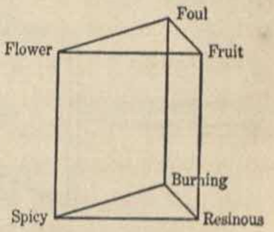

FIG. 71. — Henning's olfactory prism.

These qualities mix with the cutaneous sensations from the mucous membranes of the nose, — one quality of smoke, for example, is the same from the eyes as from the nose, — and with tastes. We usually do not distinguish the different components: if the complex comes from food in the mouth, we call the whole a taste; if from the air outside, we call the whole an odor.

Attempts have been made to connect the qualities of smell with the chemical composition of substances. In general it may be said that most odorous substances are found in the fifth, sixth, and seventh groups in the system of Mendeleeff. Haycraft has also shown that in many cases the intensity of the smell in a group increases fairly regularly with the complexity of the molecule. There are exceptions to these rules and no complete formulation may be made of them. It is probable that the chemical substance is borne on the inhaled and in less degree by the exhaled air to the olfactory nerves and there by direct chemical action arouses the nervous excitation.

Mixtures and Compensations of Odors. — Mixtures and compensations of smells can be demonstrated. For these, as for making all quantitative tests of odors, Zwaardemaaker made use of an instrument he called the olfactometer. In essentials it consists of one tube with a curved end to be inserted in the nostrils, and of a second tube of larger size containing an inner lining of the substance to be investigated which slips over the former. The amount of stimulation is measured by the area of the outer tube exposed beyond the inner. If they are even, the air entering the inner tube absorbs none of the substance on the outer; and the more the outer projects beyond the inner, the more saturated with particles is the air that enters the nostril. In the double olfactometer of this sort a tube is applied to each nostril. It is found that if certain substances, Peru balsam and iodoform, for example, are applied either to the same or different nostrils at the same time, they cancel each other and no odor is sensed. Other substances produce mixed odors that may or may not be analyzed into their components. Xylol and turpentine fuse to form a new odor, and many others can be mentioned. Certain of these mixed odors are given off by simple substances, as can be shown by the fatigue test. Thus if propionic acid be smelled for some time, the original odor will lose one of its components and assume a different quality.

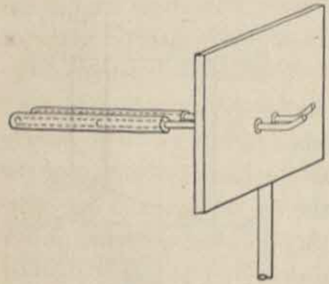

FIG. 72. — Zwaardemaaker's olfactometer. (From Titchener.)

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PROPRIOCEPTORS

The Kinæsthetic Sensations. — So far we have been considering the sensations that are received from without, what Sherrington has called the exteroceptors. These include the popularly recognized five senses of man. To these traditional five modern science has added a number of others. One of the most important and among the first to be detected of the proprioceptors is the kinæsthetic sense, the sense by which we appreciate the movements of our own members. The muscle sense had a prominent place in the English psychology of the last century, — Thomas Brown and the Mills made use of it, — but the first experimental work of importance on the subject was carried on by Goldscheider in the late eighties of the last century. Goldscheider adduced evidence that the more delicate sensitivity to movement was in the joints rather than in the muscles, as had been earlier supposed. His main bit of evidence for this was that the sensation of movement is markedly diminished if an induction current is passed through the joint as the member is bent. Evidently there are three possible sources of sensation for movement, the external skin, which must be wrinkled at the joint as it bends, the muscles and tendons which are known to be well supplied with sensory endings, and the joint. Goldscheider assumed on the basis of his experiments that the joint surfaces were the organs in spite of the fact that there are known to be no sensory nerves ending on the joint surface, and that an experiment that he made himself indicated that the membrane on the joint, the synovial membrane, had a very slight sensitivity.

Movements Perceived by Muscle and Tendon.—Goldscheider's suggestion has been subjected to much criticism. Goldscheider's method was to measure the least movement that could be noticed, with and without passing an induction current through the joint that was moved. Under normal conditions a movement of from 30′ to 1° 30′ could be detected. When the current was passed through the joint, this movement was three or more times as great. The writer and Winter repeated this experiment separately and confirmed it. They found, however, that if the current were passed through the wrist when the movement of the elbow was measured the decrease in sensitivity was just as pronounced. The sensitivity was still more reduced when the current was passed through the elbow as it was bent and the wrist at the same time. The results may be explained as due to distraction, or as due to the effects of the current upon the muscles. The muscles that bend the elbow extend over the wrist and would be affected by the current.

Von Frey believed that the sensation of pressure in the external skin was also a large factor. He found that chemical anæsthesia of the skin over a joint reduced the sensation of movement. He also proved that a patient who had had the joint removed retained the sensitivity to movement. He is convinced that sensory endings in the muscles and in the tendons are essential factors, although he would make the external skin an important element. The sensory ends in the muscles and tendons degenerate when the posterior root fibers of the cord are cut. The cell bodies of the neurones, it will be remembered, are in the posterior ganglia of the cord. The axones of these neurones constitute the posterior columns of the cord. That the joint surfaces are not primarily the sources of the sensation of movement is supported by the histological evidence that the joint surfaces are bare of sense organs, and by the fact that careful observation indicates that the movement of the elbow is ordinarily felt either in the wrist or fingers. Instead, then, of regarding the kinæsthetic impressions as coming primarily from rubbing of joint surfaces, we may regard the excitation of the sensory endings in the muscles and tendons by the contraction of the muscle or the stretching of the tendon as the source of our sensations of movement. To this may be added as a subsidiary factor the wrinkling of the joint capsule, which also contains sensory endings, and the sensations from the external skin, produced by the stretching and the relaxing of the skin by the bending of the joints.

These kinæsthetic impressions play a very large part in our mental life. It is of course important to know where the different members of the body are at any moment. In addition to this the kinæsthetic sensations contribute very largely to the coloring of other experiences; they guide the different movements and constitute an important element in the emotions. We shall have occasion to make use of them often in the later chapters.

The Static Sense. — A second important proprioceptor is found in the vesibular portion of the ear. This is not truly a sense, since its stimulation is not appreciated for itself. It is an important source of stimulation for reflexes, and we become aware only at times, directly or indirectly, of the reflexes which it arouses. This is also of relatively recent discovery. In 1872 Crum Brown, Breuer, and Mach independently reached the conclusion that the portion of the inner ear not used in hearing, the so-called vestibular portion of the ear, is closely connected with keeping the balance, and with the appreciation of the movements of the body as a whole. The evidence accumulated since is altogether convincing. The organs involved are the sacculus, the utriculus, and the semicircular canals, named in order from the vestibule. The sacculus is a membranous sack floating in the lymph contained in an enlargement of the bony labyrinth. This opening communicates with the vestibule, and the lymph is continuous with the lymph of the cochlea. A branch of the vestibular nerve enters the sacculus, and ends in hair cells. Among the hairs are small crystals of calcium carbonate, the otoliths. The utriculus is a similar, somewhat larger sack connected with the sacculus by a small opening. The nerve endings are similar to those of the sacculus. From the utriculus extend the semicircular canals, one in each plane of space. They have two openings into the utriculus, making possible a movement of the lymph through the complete semicircle. Near one opening of each canal into the utriculus are small swellings, the ampullæ. In these end the branches of the vestibular nerve that go to each canal. The nerves end in long hairs that protrude into the lymph of the ampullæ. The different branches of the vestibular nerve unite with each other and join the cochlear branch to constitute the eighth nerve. In the brain stem the two branches have separate nuclei. The nucleus of the vestibular branch has connections primarily with the cerebellum and with the nuclei of the motor nerves of the eye.

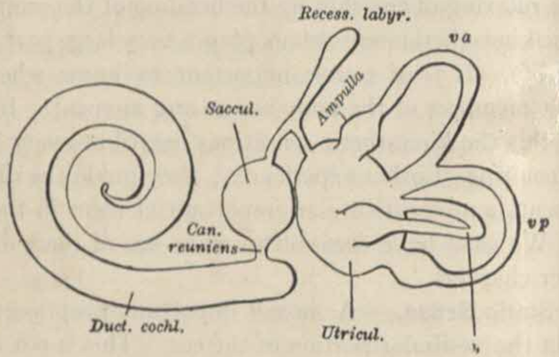

FIG 73. — The membranous labyrinth of the left ear seen from without. *va*, *vp*, the anterior and posterior semicircular canals; *h*, the horizontal canal. The relation of the sacculus and utriculus to the cochlea is also shown.

The observed functions of the vestibular organ are adjustment of the position of head and body. These are noticed primarily by the defects that appear when the organs are injured or diseased. If the semicircular canals in a pigeon are cut, the head will be held in an abnormal position, turned to one side or another according to which canal is cut. When disease affects the canals in a man there are either disturbances in the position of the head or an unsteadiness of posture. The effects of injuries to the vestibular apparatus disappear rapidly. For a few days after the operation the head will be held in a strained position, and then all sign of the operation will be lost. In this quickness of adaptation after injury the semicircular canals resemble the cerebellum. Stimulation of the vestibule by passing a strong electric current through the ears evokes a turning of the head. Many of the deaf show defects in keeping the balance. It is assumed that if the deafness is caused by an infection, the disease affects the vestibular as well as the cochlear portion of the ear in a certain proportion of cases. If the swaying

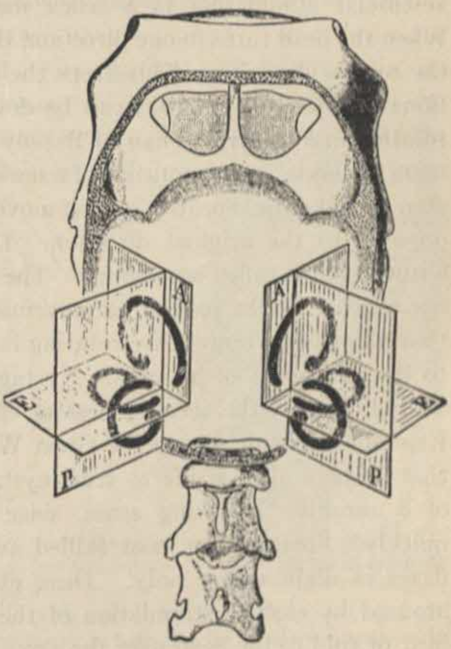

FIG. 74. — Shows the arrangement of the semicircular canals of the pigeon, looking from behind into the opened skull. In plane *A* is the anterior semicircular canal; in plane *P*, the posterior; and in plane *E*, the horizontal of Figure 73.

movements of the body are recorded accurately on the deaf it is found that many of them show larger movements than the normal. Others are normal.

Vestibular Reflex Eye-Movements. — A second effect of vestibular stimulation is a reflex movement of the eyes. When the head turns in one direction, the eyes turn reflexly in the reverse direction. This keeps the eyes fixed upon a stationary object. The reflex can be developed by continuous rotation in a revolving chair of Barañy or by merely whirling upon the heels. After rotation of a few seconds the eyes can be seen to make the repeated jerking movements in the direction opposed to the original direction. These movements constitute what is called nystagmus. The movements, which are not noticed by the patient as movements, make him believe that all external objects are rotating in the direction opposed to the movement of his eyes. Nystagmus has been used as an indicator of the sensitiveness of the semicircular canals. Experiments made during the Great War on aviators showed that it is not always safe to trust nystagmus as an indication of a sensitive balancing sense, since habituation develops quickly. Some of the most skilled aviators showed the reflexes in slight degree only. These eye reflexes can also be aroused by electric stimulation of the ears, or by applying heat or cold to the head over the ears.

A third effect of the vestibular stimulations is to cause contractions of the muscles of the stomach. In the extreme these produce the vomiting that goes with seasickness. In less degree they give rise to the vaguer abdominal sensations of vertigo or dizziness. The close and mutual connection between eye-movements, the vestibular nerve, and gastric reflexes is shown by the fact that rapid movements of the eyes have been shown to produce contractions of the walls of the stomach. If a subject swallows a rubber balloon to which a tube is attached and the tube be connected with a registering tambour that records changes of pressure on a revolving drum, it is shown that rapid eye-movements will produce slight contractions of the wall of the stomach.

Streeter[1] has shown that if he destroys the vestibular region in the tadpole, the frog that develops from it has no sense of position, is as likely to swim on its back or side as right side up. Kreidl inserted iron filings in the otocysts of the crayfish when they were opened by the shedding of the shell, in place of the particles of sand that normally find their way into the cavities at that time. After the new shell was grown he found that if he brought a magnet over the crayfish they would at once turn and swim on their backs. Evidently the attraction of gravitation for the sand particles had been replaced by the magnetic attraction for the iron filings. These various lines of experimental evidence, together with the probability raised by the close central connection of the nerve with the cerebellum and with oculomotor centers, are conclusive proof that the vestibule contains the organ for the static sense, and is the source of reflexes for many eye-movements and for

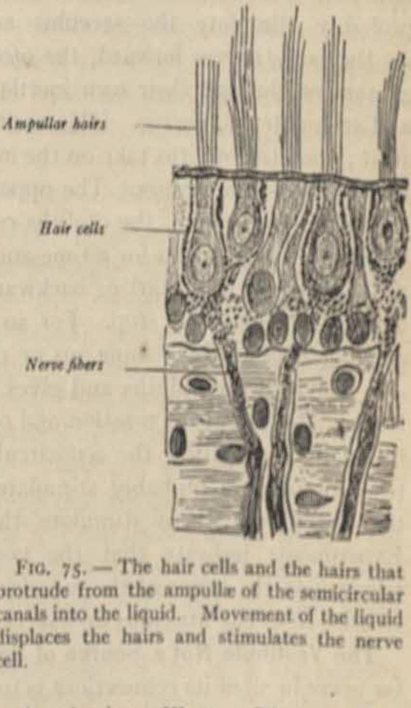

FIG. 75. — The hair cells and the hairs that protrude from the ampullæ of the semicircular canals into the liquid. Movement of the liquid displaces the hairs and stimulates the nerve cell.

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[1] Streeter, *Journal of Experimental Zoölogy*, vol. iii, p. 543.

keeping the balance, as well as for keeping the general tonus of the muscles.

The Organs of Equilibration and Their Stimuli. — The mechanism of the stimulation of the sense organs may be made out in a measure from the experimental data and the structure of the organs. Movements of the body as a whole probably stimulate the sacculus and utriculus primarily. As the body moves forward, the otoliths are left behind for a moment through their own inertia and so move the hairs and stimulate the nerves. This excitation occurs only at the start; soon the otoliths take on the motion of the body and no further excitation occurs. The opposite stimulation is given as the motion ceases; the otoliths continue to move forward under their own inertia for a time and produce the same effect as if the person were starting backward. This may be noticed as a train comes to a stop. For an instant one seems to be starting backwards. Going up or down, as in an elevator, also displaces the otoliths and gives the corresponding sensations. Movements of rotation and of turning the head in the different planes affect the semicircular canals. The hairs in the ampullæ are probably stimulated by the movements of the liquid and these stimulate the corresponding nerves. Experiments indicate that the vestibular nerves have an effect upon the tonus of the muscles. The tonic effects seem to arise from the utriculus and sacculus.

The Vestibule Not a Source of Sensations. — The vestibular nerve in all of its connections is to be regarded as the source of stimuli for reflexes, not as a source of sensations. There is a mutual relation between the stimuli from the vestibular organ and the eyes and the movements of the walls of the stomach. The vestibule stimulates eye-movements to compensate for movements of the head. It also sends stimulations that evoke contractions of the walls of the stomach. Eye-movements, vestibular stimuli and disturbances of digestion that may be assumed to be of gastric origin all give experiences of dizziness. What the origin of the dizziness sensation may be is still not determined. It seems to be localized in the head in part and probably has gastric and ocular components. It should be added that visual sensations, kinæsthetic sensations, and sensations due to displacement of the large visceral organs also aid in keeping the balance and in appreciating the movements of the body. The deaf who have lost the sensitivity of the vestibule can, by means of these other organs, still retain the balance, though less accurately.

ORGANIC SENSATIONS — ENTEROCEPTORS

Hunger and Thirst. — Of the sensations from the inner organs, hunger and thirst probably bulk largest in the daily life of man. Hunger has been investigated by Carlson and by Cannon.[1] They find in man and dogs that it is a comparatively transient accompaniment of the deprivation of food. During a period from three to five days after food is stopped, the sensations become continually weaker and gradually practically disappear. They are, however, rearoused by sight of food or by anything that suggests food. The sensations were found to be due to contractions of the walls of the stomach. Records of these contractions were taken by swallowing a rubber sack or balloon with tube attached which could be inflated to fill the stomach, and then registering, upon a revolving drum, the compressions of the air in the balloon. These contractions are particularly vigorous when hunger is keenest, and in general run parallel to the sensations. Cannon has also exhaustively confirmed the previous opinion that thirst has its seat in the back of the mouth. It is due to the drying of the mucous membrane there. It may be relieved by laving the back of the mouth with citric acid or by taking liquid into the system, either through the mouth, through an artificial opening into the stomach, or directly into the circulation. Each of these processes leads to the moistening of the membrane in question.

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[1] Cannon, *The Physiological Processes in Pain, Hunger, Fear, and Rage*, 2d ed., 1929, New York.

General Sensibility and Sensations from Internal Organs. — To these more definitely known receptors and sensations we must be prepared to add others as knowledge develops. These fuse for the most part into a general mass of awareness of well-being or ill-being and are not known separately. Some have names ascribed to them in popular speech. Of these, the more external, of tickling, pins and needles, itching, have been explained in different ways; pins and needles by changes in circulation; tickling by contractions in the skin muscles, survivals of the fully developed skin muscles in animals, etc. No one of the explanations can be regarded as more than hypothetical. The internal sensations are even less known and few if any distinctive names can be given. The sensitivity of the alimentary canal was studied by Boring. He stimulated the upper end as far as the stomach and the rectum. All parts investigated were found sensitive to warm and cold, mechanical and electrical stimulation. When intense all gave rise to pain. The stomach and rectum were sensitive to hydrochloric acid and alcohol. Goldscheider, on the basis of clinical reports, states that the tissue of lungs, liver, heart, kidneys, and gall bladder are insensitive. In most cases, the membranes attached to or surrounding the organ are sensitive when the organ itself shows no sensitivity. Most of these internal sensations are important for emotional experience and we shall consider the problem anew in that connection.

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THE DOCTRINE OF SPECIFIC ENERGIES

The Doctrine of Specific Energies. — A final problem is the bearing of the results so far discussed upon the doctrine of specific energies. We have found that law convenient as an introduction to the study of sensation, and have used it as a guide throughout. But it is now time to determine how accurately our hypothesis harmonizes with the facts. The doctrine for convenience may be divided into different parts. (1) A nerve end when stimulated at all always gives rise to its own peculiar sensation. (2) There are as many nerve ends as there are specifically different sensations. (3) The quality of the sensation depends upon the character of the end organ rather than upon the nature of the stimulus.

If we examine these phases of the doctrine one by one, we find that the first holds so far as it is possible to test it at all accurately. It applies to the retina, to the end organs on the skin and on the tongue, less certainly to the olfactory organ. In discussing the problem we distinguish adequate from inadequate stimuli. An adequate stimulus is one that excites the organ in greatest perfection. Light is an adequate stimulus for the eye, sound waves for the ear, etc. Adequate stimuli give the full number of sense qualities of which the organ is capable. Other stimuli are inadequate. The electric current is an inadequate stimulus for all senses, pressure an inadequate stimulus for the eye, etc. Each of the sense organs mentioned may be excited by one or more inadequate stimuli, and when excited responds with a sensation of the quality peculiar to that sense. The number of stimuli that will excite the organ and the intensity of stimulation required vary from organ to organ and for the different sense qualities within the same organ. The sensation that arises when the organ is stimulated also shows various degrees of approximation to those excited by the adequate stimulus. On the skin, most of the organs may be excited by several stimuli and give approximately the same quality as that produced by the adequate stimulation. The olfactory endings are excited with difficulty and then, so far as is known, only by electrical stimuli, and the resulting quality is very uncertain. The location of the organ may account in part for the uncertainty of the result. The retina has an intermediate position in both respects. Mechanical and electrical stimuli at least affect it, and they produce several sensory responses, but not the variety or delicacy of effect produced by the light waves. While the law does not hold with the completeness that a firm believer might wish, still it can be said in general that sense organs may be affected by various stimuli, and when they respond, *if they respond at all*, the quality is that ordinarily given by that organ rather than the quality produced by the stimulus in the organ for which it is the adequate stimulus.

The second law is less definitely demonstrable. Except on the skin, one cannot prove that each sense quality has a separate nerve end. From what we know of the eye, the cones probably have more than one sense quality, and while one might assume that there are different sensitive substances in each cone, it is hardly likely that there are different nerve ends. A case might be made out for separate taste buds for each quality; there is slight evidence for separate organs for each odor. In hearing, the Helmholtz theory is suggested by the law rather than being substantiated by it. Strictly, then, the statement that there are as many qualities as there are sense organs and no more holds only for certain senses, and is to be regarded rather as a convenient guide to the discussion of sensation than as a fully substantiated fact.

The third principle, that the quality of sensation depends upon the sense organ excited rather than upon the stimulus, holds approximately. Adequate stimuli excite the organ at a slighter intensity and give a richer quality in most of the sense organs. Nevertheless if one were to decide between the receiving organ or the external stimulus as the determinant of the sensory quality, the receiving organ must be given the more important part.

There is also a question whether, granted that the sensations depend upon the specific characteristics of the nervous system, the determinants of the quality are to be found in the sense organ or more centrally in the nerves or their brain connections. The evidence is conflicting from sense to sense. According to Nagel[1] there is no good evidence that colors can be excited except from the retina. Cutting the optic nerve or turning the eyes sharply to one side or the other gives rise to sensations of light, but he thinks both probably due to the accompanying pull upon the retina. Sensations of taste are with difficulty or not at all excited by inadequate stimuli upon the tongue, while mechanical stimuli upon the chorda tympani where it passes through the middle ear arouse them certainly and at comparatively slight intensities. In the skin it is apparently the end organ that gives the peculiar quality. Pressure upon the ulnar nerve gives sensations but not of the distinct qualities that may be aroused from the skin. One has little basis of decision between the sense organs and the cortex. The nerves give no evidence of being specific, but they should be if the sense organ determines what sensations shall be received. In this connection it is interesting to speculate as to the relation between the electrical and the chemical contributions to the conduction. Since Adrian's work that emphasized the electrical phase by showing that the rate of oscillation varies with the intensity of stimulation, there is a tendency to assume that the electric current is the entire factor in nerve propagation. Were this the case, all nerve processes between sense organ and cortex at least would have exactly the same character. This omits consideration of the chemical component of nervous conduction which is essential to the modern theory. We know nothing of differences in its character in different nerves, but it does leave open the possibility of some conduction that might be peculiar to the nerves of each sense.

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[1] Nagel, *Handbuch der Physiologie*, vol. iii, pp. 1-15.

The Specific Activity of the Cortex. — We know little more about whether different areas of the cortex have specific ways of responding. The practical agreement that there is a definite localization of sensory functions would harmonize with that assumption. Occasional reports of stimulation of the cortex of a patient whose brain has been exposed for an operation, and who is not under an anæsthetic show that kinæsthetic and visual sensations may be induced by inadequate stimuli applied to the cortex. Lafora[1] reports that stimulation of the occipital cortex of an ape evokes movements as if he were attempting to manipulate a seen object where no object is present. These bits of evidence are too few to be conclusive, but so far as they go speak for rather than against a specific function of the cortex. The whole problem of what aside from the connections is the determiner of specific character of conscious qualities is largely still an open one. What evidence we have tends to favor rather than oppose the doctrine of specific energies. On disputed points evidence is lacking rather than opposed to the doctrine.

Sensation Intensities — Weber's Law

Sensation intensities offer an entirely different problem from qualities. Qualities, as we have seen, are ordinarily named, may be referred in some cases to sense organs, offer points of discrimination that may be recalled in memory, — in general they stand out for themselves. Intensities, on the contrary, have none of these characteristics. We think of a sound as very faint, moderately or very loud, but that is all. Intensities have no real designations, and cannot be remembered at all accurately. It is perhaps not one tenth as bright in this room today as it was when last the sun shone, but you do not appreciate the difference accurately. You think of this as a moderately dark day, but have little idea how much darker than yesterday. The same holds of weights. Most persons have great difficulty in deciding whether a package of an unknown substance weighs one pound or two, and would be altogether at a loss to decide whether more energy was exerted on the ear by a telephone held close to it or by a steam whistle at a distance.

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[1] Eighth Internat. Congr. of Psych. Proc., pp. 337 ff.

Weber's Law. — Most of the attempts to deal with the intensity of sensation have been related to some earlier experiments of the German physiologist, Weber. Weber found in several senses that differences in intensity that could be just noted were not absolute values but were relative to the quantities compared. Thus Weber found that if a weight of 32 ounces were lifted, it could be noted that 30 ounces was just less, while if 32 drachms were lifted, 30 drachms could just be noticed to be different. A difference of a fifteenth of the total weight could be noted whether the units were ounces or drachms. These relatively crude experiments have been repeated and improved upon by a number of later workers, Fechner in particular, and show the same general law. The fraction of the total intensity that may be just noticed varies from one sense to another, but holds with fair accuracy for the same sense. The values range from approximately $\frac{1}{100}$ for sight to one third or one fourth for smell. In giving these values, it should not be assumed that the just noticeable difference is absolutely constant even under constant objective conditions or under conditions that are as nearly constant as can be obtained. Differences in the order in which stimuli to be compared are given, in the degrees of attention at different times, and in the way in which the suggestions that may be given unintentionally may work, all have an influence upon the determination of the difference limen. In consequence, it is not often that two consecutive trials will give the same result. All values given are averages obtained with the same individual, and where several values are given it is assumed that the two are extremes for the subjects used.

Psychophysical Methods. — The variability in the results of separate tests made necessary the development of methods to derive the most probable true value from the varying results obtained. The simplest and one much used is the *method of minimal changes*. In essentials it consists in having one standard stimulus and one that can be varied. The standard is given first and then the variable is set at a value so low that there can be no difficulty in distinguishing it from the standard. The person experimented upon, the observer, is asked to say whether the available stimulus is greater or less than the standard. The variable is then changed by small steps and compared with the standard until he says that the two are equal. The two weights are then made equal and compared and the variable gradually diminished in intensity until it seems less than the standard. After a number of comparisons have been made, the results are averaged. A similar procedure is followed giving the variable first and the variable second each time. If the time of giving the stimulus influences the judgment this 'time error' will be eliminated by averaging the two. All similar possible sources of constant errors, that is errors that depend upon the conditions of the experiment, can be obviated.

The Method of Right and Wrong Cases. — A method that depends upon the calculation of the probability of errors uses only two stimuli and these are not varied. This is the method of constant stimuli or right and wrong cases. The two stimuli are chosen sufficiently alike that mistakes are frequently made. The observer is asked to say only whether one is greater or less than the other. From the law of probability it is possible to calculate from the number of mistakes made in comparing any one difference, what difference is just as likely to be judged right as wrong. This is assumed to be the value that would be right in 75 per cent of the cases. Other methods have been applied to check the results, but these two are most used.

The Fraction of the Difference Limen. — The fraction of itself that must be added to a given intensity to obtain the one that is just noticeably more intense varies widely for different senses. The fraction for vision ranges from $\frac{1}{62}$ to $\frac{1}{167}$ for different observers and different intensities. For hearing, Wien, using telephone tones, obtained a fraction of $\frac{1}{3}$ to $\frac{1}{4}$; for pressures, values have been obtained from $\frac{1}{10}$ to $\frac{1}{30}$, depending upon the part of the body stimulated. Lifted weights give a much smaller value than passive pressure, from $\frac{1}{40}$ to $\frac{1}{125}$, according to Biedermann and Lowitt, according to Weber $\frac{1}{40}$. Taste, smell, and temperature all offer difficulties in the technique, and the results are correspondingly unsatisfactory. The values of the fraction for these senses are generally given as ranging from $\frac{1}{3}$ to $\frac{1}{6}$.

Departures from Weber's Law. — Weber's Law holds fairly accurately for the general range of intensities. The fraction is usually greater for the extreme intensities, and even within what may be called the mean values, there is often a gradual change. The first fact can be seen in many of the simple phenomena of daily life. The increase in the least noticeable difference at maximum intensities is illustrated in the difficulty in reading when the sun is shining on the page. The difficulty in reading in faint light illustrates the increase of the relative difference at the lower range of intensities. The relative amount of light reflected and absorbed is the same at all intensities, but the relative difference that may be discriminated is much greater at the extremes of absolute intensities. Were relative differences discernible with equal ease at all intensities, one could read as readily by moonlight as by electric light, and in the glare of the sun as well as in the shade.

The Limen for Sensation. — The results of the investigations of the least intensities that can be perceived, the absolute sensation limen, have also been determined for certain senses with a satisfactory degree of accuracy. For sight and sound the values can be given in terms of absolute units. Langley found that the eye was sensitive to light waves that exerted an energy of .00000003 erg. Wien found that the ear would respond to still smaller values: from .000004 erg for tones of 50 V D per second to .00000000000000005 erg for tones of 3200 V D per second. For pressure, the most reliable results are those given by von Frey. He found the energy required to excite a hair to be about $\frac{1}{50}$ of an erg, and to excite a pressure spot on the skin about $\frac{1}{3}$ of an erg. Values obtained for other senses have relatively little meaning, as they cannot be stated in terms of energy.

Interpretations of Weber's Law. — Many interpretations have been given to Weber's Law. Fechner formulated it as a definite relation between stimulus and sensation. The simplest of his statements was that sensations increase in arithmetical ratio when stimuli increase in geometrical ratio. One must multiply the auditory stimulus by $\frac{1}{5}$ each time to give rise to a sensation that is just noticeably greater. That he thought of as adding one unit to sensation. Fechner also stated this relation to be that the sensation varies with the logarithm of the stimulus, since to multiply one merely adds logarithms. Fechner also thought it possible to use the just noticeable difference between sensations as a measure of sensations. He thought one could say that the brightness of a light could be defined in terms of the number of distinguishable differences between the faintest light that could be seen and the light to be measured. The only application that has ever been made of the principle has been by the Bell laboratories for the measurement of tones. They determined the average difference limen for tones and chose a unit of approximately this value to determine how far above the absolute limen any given tone may be. They call the unit a decibel. The logarithm of the physical unit is a constant. In consequence the physical unit varies with the distance above the limen. An idea of the value may be given by the statement that the value of the ordinary speaking voice is about 70 decibels. That means the ordinary person could distinguish some 70 different intensities between the faintest tone that could be heard and the voice tone.

Fechner's use of the difference limen as a unit of measurement has been questioned. Von Kries, one of the strongest critics, asserts that the difference limen is really an intensity that just fails to be distinguished and so is defined only by negation. One cannot, he says, use a negative value as a positive unit. Stronger is the practical objection that the value could at best be determined only for an average individual. Even for that individual, one could never hold the conditions constant from day to day, and so begin the series of measurements on one day where one left off the day before. This objection does not hold for the decibel, which is defined in physical terms only. Theoretically if one is to have a unit for the measurement of sensations as sensations it should be a unit that is definitely conscious. The difference limen is not conscious and can be determined only by a relatively elaborate experiment.

Much discussion has been given to the question of how Weber's Law is to be explained. The law may express the relation between intensity of stimulus and nerve impulse. Unfortunately no measurements have been made of the relation between the absolute intensity of the stimulus and the rate of oscillation of the action current. Probably Weber's

Law is an expression of the relation between the intensity of the stimulus and the corresponding chemical reaction in the tissue of sense organ or nerve. We know roughly that the chemical reaction becomes relatively less and less the more intense the stimulus applied.

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CHAPTER VI

INDIVIDUAL DIFFERENCES

WE may regard the material presented so far as giving the facts which must be taken into consideration in discussing any phase of psychology. The nervous system is involved in all acts simple or complex, motor and sensory, high or low, the more mental and the more physical. The sensory processes provide the stimuli to actions and the bases of all knowledge. Whether we consider man's behavior objectively or his mental life in a more unitary and subjective way we must use the results of both forms of investigation in coming to our conclusions.

The More General Ways of Classifying Man's Capacities. — Before we go to a discussion of the more isolated problems of psychology, we need to consider a number of ways in which man's capacities may be grouped for treatment. Both in practice and theory it is frequently desirable to know with what kind of an individual we are dealing. For this purpose it is necessary to classify individuals with reference to different capacities. As a preliminary to the classification of individuals one needs a grouping of the capacities themselves. Various classifications have been made at different stages in the history of the science. First was recognized a division into the intellectual capacities and the appetitive or the emotional and active phases of mind. Later came a division into intellect or sensation, feeling or emotion, and will. Some traces of the last have been continued down to the present. All of these are now recognized as too rigid and strict to be used at the present stage of knowledge. These terms may be used for rough popular classifications, but cannot be accepted as final.

Intelligence. — Of all the various capacities which have been mentioned intelligence has received most emphasis in recent psychological work. Numerous measurements have been developed for intelligence although we do not have any satisfactory definition for it. Intelligence has been defined as the ability to appreciate a purpose and to manipulate means to that end. The tests that have been used to measure intelligence are mostly of ability to learn or to make use of previous learning. Incidental to the definition is the ability to adapt to one's surroundings. Ability to get on as indicated by the profession in which one succeeds or the salary received has some value as an indication of intelligence. If we accept the usual methods of measuring, learning and problem solving are important factors in the complex of capacities we designate as intelligence. Practically all the characteristics of a man that are connected with the knowing side are implied in what is called intelligence.

The Measurements of Intelligence. — Intelligence has occupied a large place in the practical activities of the psychologist in the last few years from the demand there has been to measure it. Measurement came first in response to a definite demand. A ruling was made that pupils should not be admitted to the French schools unless they were intelligent enough to profit by the training. The authorities at once turned to Binet, professor of psychology at the Sorbonne, with the request that he devise a means to determine who was able to meet this test. Binet had conducted experiments on the intelligence of his own daughters which provided a tentative survey of the problem. When the specific demand came for a scale of intelligence he utilized some of the methods he had developed for testing them. He really had the first clew to final success only when the idea came to him that it would be possible to use the attainments of the average child at successive years of his life as a standard against which he could place the adult for comparison.

The Age Scale. — After it had been decided that children of different ages offered the best scale to which to relate the intelligence of the adult, the necessity arose to discover a series of tests that could be applied to each age to determine the average capacity at that age. Binet associated with himself Simon, a man of school experience. Together they made use of Binet's earlier results to select tests that could be passed by children of each age. The tests were graded purely empirically on children of each age selected at random from the Paris schools. Later workers have decided that Binet's children on the average had a lower intelligence than the general run of the population because they were chosen from the lower classes in the social scale. On the selected children tests were made of different tasks and those were assigned as valid for an age which the average child of that age could pass.

Improvements of the Scale. — Binet made two revisions of his first scale and in 1911 prepared a series of tests for each of the years from three to ten and for the twelve and fifteen year child and for the adult. Binet stated the intelligence of the child in terms of his mental age without reference to the chronological age. This was satisfactory for the unintelligent adult, but did not give a complete picture for the growing child. Binet's scale was soon translated and adapted for the different countries of Europe. In America Goddard early made a translation. Terman in 1916 published a revised set of tests that had been based on the Binet tests and which was checked on 900 California school children. This Stanford Revision as it was called is still the most widely used in America of the individual tests. Terman based his procedure upon Binet's. Probably the most important advance consisted in adding the intelligence quotient to the mental age. The intelligence quotient is defined as the mental age divided by the chronological age. The advantage of the intelligence quotient over the mental age as an index lies in giving a single term a value that involves the actual age as well as ability.

The Intelligence Quotient. — The intelligence quotient, I. Q., remains fairly constant for the average child through his life. If he is a year behind at four he will be about two years behind at eight. Recent work indicates a tendency for the superior child to have his intelligence quotient increase with his age and for the dull child to have his quotient decrease. A limit to the constancy of the I. Q. is set by the test itself. Terman gave no tests beyond eighteen. Giving credit for passing all the extras makes the highest score possible a mental age of nineteen and a half years. Terman assumed that the average individual reaches his maximum intellectual development at sixteen. In consequence he assigns to adults and to children older than sixteen a chronological age of sixteen. Dividing nineteen and a half by sixteen shows that the maximum I. Q. possible for an adult is little more than 1.20. Should a child of twelve pass all of the tests he would have an I. Q. of 1.60. So far as the test could show this child would each year have a lower I. Q. on the test simply because if his mental age increases it cannot be measured. Two sets of tests for sample years give an idea of the sort of tests used by both the Terman and the very similar Binet test.

TYPICAL TASKS IN THE STANFORD BINET TESTS

For 3 years

Points to parts of body: nose, eyes, mouth, hair (3 of 4).
Names familiar objects: key, penny, closed knife, watch, pencil (3 of 5).
Enumerates at least 3 objects in a simple picture.
Gives sex.
Gives last name.
Repeats 6 to 7 syllables (1 of 3).

For 9 years

Gives the day of week, month, day of month within 3 days, year.
Arranges 5 weights in order of magnitude.
Makes change for amounts under 25¢.
Repeats 4 digits backwards.
Makes a sentence of 3 simple words.
Gives 3 rhymes for 2 of 3 words.

Group Tests. — Since individual tests require more time than can be given when large numbers are to be tested, methods have been devised for measuring the intelligence of large groups at one time. The best known of these are the Army Tests devised by a group of psychologists for the measurement of the soldiers in the United States army during the war. The tests consisted of 212 tasks printed on a form. The men were examined in groups of one hundred or so. The examina-

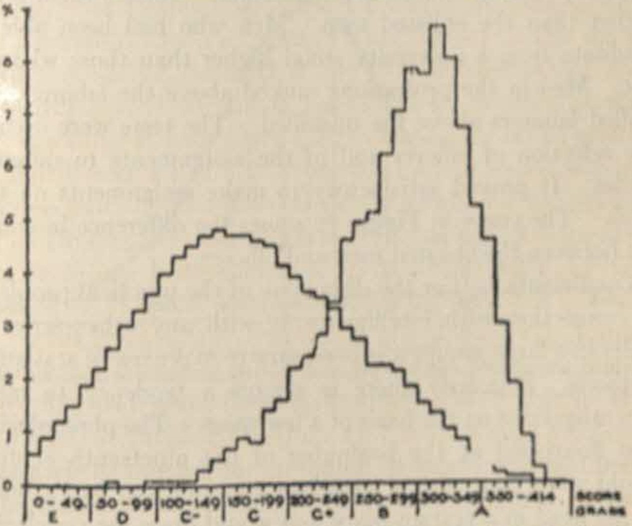

FIG. 76. — Shows the relative success of officers and privates in the Army Test. The steep curve to the right shows the distribution of 5563 officers. The lower curve to the left shows the distribution on a different scale of 63,647 enlisted men. The higher standing of the officers stands out clearly.

tion consisted in writing the answer to each problem, on the blanks provided. The scoring was on a percentage basis. The men were divided into letter grades. *A* was assigned to men who made scores of between 135 and 212; *B*, to those who made grades between 134 and 105; C^+, to those between 104 and 75; *C* to those between 74 and 45; C^- to those between 44 and 25; and *D* and D^- to the others. A close relation was found between the standing in these tests and in the Terman tests, and also between the standing in the tests and various social and business attainments. Officers rated much higher than the enlisted men. Men who had been able to graduate from a university stood higher than those who did not. Men in the professions ranked above the laborers and skilled laborers above the unskilled. The tests were used in the selection of officers and in the assignments to different duties. It proved satisfactory to make assignments on this basis. The curve in Figure 76 shows the difference in standing between the enlisted men and officers.

Coefficients. — For the discussion of the practical problems in connection with intelligence as with any other series of traits in a large group, it is necessary to make use of statistical methods. Popularly there is always a tendency to make generalizations on the basis of a few cases. The phrenologists who flourished at the beginning of the nineteenth century would see a man with a voracious appetite who had a bump on his head in a certain place and would draw the conclusion that a bump in that place would always indicate a great appetite. In spite of twisting the facts adroitly to satisfy their theory, they soon came into disrepute. It was found that many individuals with pronounced appetites had no protuberances, and the bumps were large in individuals who did not have unusual appetites. At present it is accepted that to determine whether one character, such as the protuberance, has any connection with an appetite, it is necessary to make use of a rather elaborate method. You may find one case in which two marked characteristics are found together and have no indication at all there is a real connection between the two.

Distribution of Biological Characteristics. — Intelligence like height or any other physical characteristic is distributed in the population in accordance with what is known as the probability curve. There are always a large number of individuals near the average in any one of the measurements that may be made and the number for each unit becomes fewer and fewer as the values are farther and farther from the average. There are very few individuals who are six feet six inches tall or five feet tall, but a great many cluster about the average height for a given race. Figure 76 shows the average distribution of the soldiers in the intelligence tests. It is closely similar to the curve which shows the height of the same men (Fig. 77) or to a curve that shows the frequency of occurrence of a purely chance event. The curve is also identical with the curve that would be made were the errors made in shooting at a target plotted on the same basis. Small deviations from the bull's

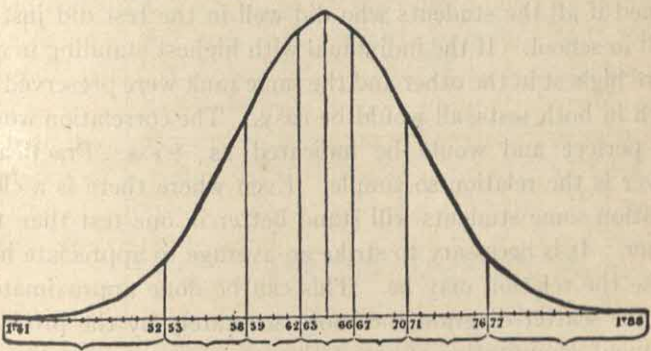

FIG. 77. — The distribution of stature among French soldiers. The distances on the horizontal axis indicate the height in centimeters on the vertical axis, the number of men of heights between the figures printed below the line. (From Bertillon, " Instructions signaletiques.")

eye are very numerous. The larger the deviation in any direction, the fewer they are. The Gauss formula makes possible determination of any one part of the curve from any other.

The Coefficient of Correlation. — When it is desired to determine if there is any real connection between two traits, each of which is distributed in this chance way, it is necessary to use a definite mathematical treatment. The relation between standing in a test and in school could be simply determined if all the students who did well in the test did just as well in school. If the individual with highest standing in one were highest in the other and the same rank were preserved by each in both tests, all would be easy. The correlation would be perfect and would be indicated as +1.0. Practically never is the relation so simple. Even where there is a close relation some students will stand better in one test than the other. It is necessary to strike an average to appreciate how close the relation may be. This can be done approximately by the scatter diagram and more accurately by the product-moment computation of correlations.

The Graphic Representation of Correlation. — A simple method of obtaining a rough idea of the degree of correlation is offered by what is called the 'scatter diagram.' Take a sheet of cross section paper and mark along its edge at the left in convenient units the range of the scores made in the test. Mark along the top of the paper units corresponding to convenient units of grades in school. Then put a line for each student on the row corresponding to his score in the test at the point which is above the point on the base corresponding to his standing in the school. In the completed diagram the degree of scatter will indicate the closeness of correspondence between the two ways of measuring ability. If the diagram shows a narrow band of marks extending at an angle of forty-five degrees with the base from the lower left hand to the upper right-hand corner of the cross section paper, the agreement will be close and will be positive. If there should be a similar narrow band extending from the upper left-hand corner to the lower right-hand one, the correlation would be high but negative. That would mean that the better a student did in the test the worse he would be in school. The test would be useful but must be used in the opposite way from that in which it was planned. Where the marks are scattered irregularly over the paper, it means slight or no correlation. A scatter diagram representing an average correlation is shown in Figure 78. The coefficient of correlation for this data determined by the product-moment method is 0.49. Other data are used in the example on page 220.

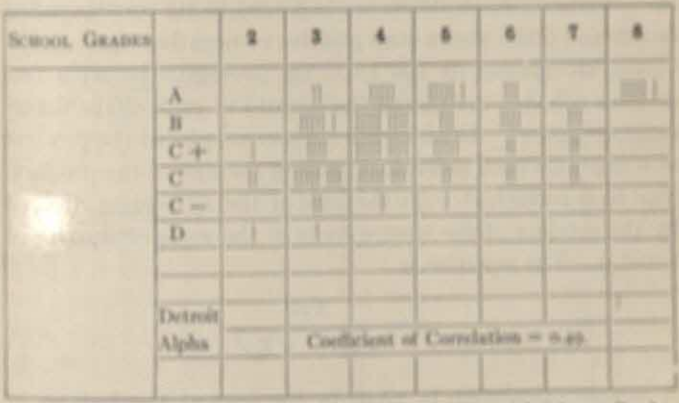

FIG. 78. — Scatter diagram of moderate correlation, Social Science Grades, Detroit Alpha.

The Product-Moment Method. — A numerical value may be given to the relation of two distributions by a method first worked out by Karl Pearson. The method depends upon determining the number and amount of the deviations from the average in each of the capacities to be compared. First find the average standing of the group in each of the capacities to be correlated. One may be designated as the x the other the y values. A table may be made. In a first column give a list of the individuals tested. Then arrange the individual scores of the individuals in two columns under x and y. Each value in the x column is subtracted from the average of the x values and each value in the y column from the average of the y values. Each difference is placed in its corresponding fourth and fifth column with positive or negative signs, as the values are greater or less than the average. In sixth and seventh columns are placed the squares of each of the differences, x^2 and y^2. In an eighth column are placed the product of x and y for each individual, stating the sign of the product. The final coefficient, r, is the sum of the xy column divided by the product of the square roots of the sums of squares of x and y. The equation is

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2} \cdot \sqrt{\Sigma y^2}}.$$

A sample calculation is given in the note at the bottom of the following page.

The Interpretation of Correlations. — Where the x and y values for a given individual are on the same sides of the average and at approximately the same distance from the average, the coefficient of correlation will be high; where some are on one side of the average and others are on the opposite sides, or where they differ greatly in the distance from the average, the coefficient of correlation will be small. Should most individuals have scores above the average in one test, and below in the other, correlation would be negative. High correlations may be interpreted to mean that there is some essential connection between the capacities that are involved in the two tasks. A negative correlation would indicate an essential incompatibility between the two tasks that makes success in one go with failure in the other. Correlation coefficients of

1.0 or of − 1.0 are practically never found. Correlations as high as 0.90 are rare. On the other hand to have any significance correlations should be above 0.20, unless a very large number of measurements have been made. In the Army experimentation it was found that the correlation between the Intelligence Quotient by the Stanford revision of the Binet and the Alpha form of the Army test ranged between 0.80 and

Individuals	Scores in Arith.	Scores in Geom.	x = Diff. of Scores in Arith. from Aver.	y = Diff. of Scores in Geom. from Aver.	x^2	y^2	$x \cdot y$
1	70	55	− 14	− 19	196	361	+ 266
2	75	92	− 9	+ 18	81	324	− 162
3	80	60	− 4	− 14	16	196	+ 56
4	82	65	− 2	− 9	4	81	+ 18
5	84	50	0	− 24	0	576	0
6	85	65	+ 1	− 9	1	81	− 9
7	88	96	+ 4	+ 22	16	484	+ 88
8	88	87	+ 4	+ 13	16	169	+ 52
9	92	80	+ 8	+ 16	64	36	+ 48
10	96	90	+ 12	+ 16	144	256	+ 192
Average	84	74			538	2564	549

r = coefficient of correlation
Σ = sum

$$r = \frac{\Sigma x \cdot y}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{549}{\sqrt{538 \times 2564}} = \frac{549}{1174.49} = .467\ (.47).$$

The calculation above shows how a coefficient of correlation is computed. This sample gives the relation between the standing in a course in geometry and the standing of the same individuals in arithmetic. The first column lists the individuals. The second column gives the actual grades in arithmetic, the third column the grades of the same individuals in a class in geometry. At the bottom of each column is the average. The fourth and fifth columns contain the deviation of each individual from the average with a minus sign when below the average and a plus sign when above the average, for arithmetic and geometry respectively. The sixth and seventh columns give the squares of the deviations in each subject. The eighth gives the products of the deviations from the average of the same individual in each subject. This respects signs. Where both are on the same side of the average, the product is positive, where one is above, the other below, the product is negative. The sum at the bottom of the column considers signs, so the more that are on the same side of the average, the larger the sum.

The computation is indicated below. The xy gives the numerator of the fraction, while the denominator is the square root of the product of the sum of the squares. The denominator is constant, while the numerator varies with the similarity of the standing in the two subjects. Were the standing of the same individual exactly the same in the two subjects, xy would be equal to the sum of one set of squares, and the quotient would be one. The greater the departure from this similarity, the smaller is the fraction. It approaches zero as a limit.

0.86 for different types of individuals. This is an instance of a high correlation. Correlation between most mental tests and standing in college is between 0.35 and 0.45. This means that a test gives a slight idea of what a student will do in his work, but that it is a comparatively slight indication.

The Conditions of Intelligence. — Accepting intelligence as capacity for adjustment to social conditions, one may well ask what determines intelligence. The first general question to arise is whether intelligence is more dependent upon heredity than upon environment. In favor of heredity we have the moderately high correlation between the standing of parents and children in tests or the success in practical life. Jones found a correlation of 0.59 between scores made by parents and by their children. Siblings, *i.e.* brothers and sisters, were found by Willoughby to show a correlation of 0.42 in various mental tests. Twins show a higher correlation than do siblings. For identical twins, twins assumed to develop both from one ovum (0.67), the correlation is higher than for the non-identical (0.41). The absolute correlations determined by different authors vary from 0.67 to 0.88 for the identical twins and are from 0.40 to 0.60 for ordinary twins. Tests by the same man under the same conditions show twins to have higher correlations than siblings, and identical twins than the non-identical twins. These relations all indicate that heredity has a great influence upon intelligence. The intelligence of a child is determined very largely by the intelligence of the father and mother.

Influence of Environment upon Intelligence. — In the early years of testing the tendency was to make heredity the all-important factor in determining intelligence. Recently there has been a slight shift towards allowing environment some place in the scores that are made. Burks and Freeman attacked the problem separately by a study on different groups of the correlation in intelligence between adopted children and the intelligence of the foster parents. Both find that the foster homes have a decided influence upon the intelligence. Burks finds that a good foster home may raise the I. Q. by as much as twenty points, and a bad home may lower it as much. Freeman estimates the average influence at about seven and a half points. All agree that while environment affects the ability to pass a test, heredity contributes about seventy to eighty per cent to the capacity.

The general conclusion is reinforced by study of other environmental factors. Tests at different ages of children who live under special handicaps show a gradual deterioration in ability to pass tests. An instance is the canal boat children of England and the continent who spend all their time on the boats and have little opportunity to attend school. Early these children are little behind the ordinary child in the tests. They fall farther and farther back as they grow older. Tests of the deaf show the same tendency. There is progressive deterioration in I. Q. as measured by tests as the child grows older. How much of the effect of lack of schooling or lack of contacts of the deaf is due to real effect upon intelligence and how much to the dependence of the tests upon language and information derived from the environment, is very difficult to decide. Intelligence, by definition, is intended to apply only to potential ability and not to the effects of training. All tests do use language and depend for their success upon knowledge that the ordinary child derives in school or from his fellows. Reduce these contacts and the intelligence seems to be decreased. It is apparently impossible to measure potential ability without using knowledge acquired through training.

The Degrees of Intelligence. — Important for society are the differences in intelligence of its members. Adults range in ability from a mental age of two or less to the highest abilities of the genius. The lower grades must be kept in institutions all their lives. Others can be self-supporting and capable of living freely in the community, but cannot be expected to perform other than the humblest tasks in society. An older classification has been redefined in terms of the I. Q. Idiot is the name given to individuals whose I. Q. is less than 20; imbeciles are those with an I. Q. between 20 and 50; and those between 50 and 70 are designated morons. The normal range is between 90 and 110. Those who are below normal and not feeble-minded are called dull, while those with an I. Q. above 110 are designated superior. The idiots need institutional care and cannot be trusted in the institution to meet their simplest needs. Imbeciles also should be kept in institutions, but can be taught to care for their personal needs and perform simple tasks. Morons can be socially independent and make a living in the simplest occupations. The dull and normal tend to enter occupations in accordance with their abilities.

The Feeble-Minded in Society. — The treatment of the individuals of the lower grades of intelligence in the community is an important and difficult problem. The Army tests showed that some two per cent of the population is below the level of intelligence which is required for keeping afloat in the community. The lowest of these are sent to institutions, but the moron class is left at large. Many of these come into conflict with the laws. Most cities now have clinics in connection with the courts, especially the children's courts, where offenders may be tested for intelligence. The results of the tests are used in determining what shall be done with the offenders. If a child is in the lower grades of intelligence, he needs either special treatment prolonged over a long period, or to be definitely committed to an institution. The ordinary methods of reform schools are of no value. A knowledge of the intelligence of adults is also necessary if the punishment is to be appropriate to the offense. The proportion of feeble-minded among criminals is larger than among the general population, although Murchison found the average intelligence in prisons to be not much different from the general population. Minor offenders are of lower grade than those guilty of major crimes.

Intelligence and School Progress. — One of the important instances of the relation of intelligence to practical efficiency is seen in the progress through the schools of individuals who possess different degrees of intelligence as indicated by the tests. Children with less than the normal I. Q. are always retarded in their school grades. Children of more than normal intelligence are frequently ahead of the normal grade for their age. The schools tend to promote by age rather than capacity, so there are fewer children ahead of their normal grade than behind. The age at which children leave school is inversely proportional to their intelligence. The dull children fall farther and farther behind, then become discouraged and give up school as soon as the law permits. Few children with an intelligence quotient less than 100 complete high school. College students are mostly above 100. School training, at whatever level, does not change the fundamental intelligence of the individual. The schools are, however, a selective factor. They eliminate the child at the level which his natural intelligence permits him to attain. If no unusual factors are at work, the advancement in school or the grade attained by an adult gives a fair indication of his intelligence.

Sex Differences. — Many comparisons have been made between the success of boys and girls in the tests. Most agree that girls do a little better than boys in the ordinary tests. Analysis of the separate items in the tests shows that girls are more superior in those which depend upon memory and care. The boys do better in tests which require mechanical ability and problem solving. Most tests have rather lower of the latter type than of memory items. In consequence the girls make a better showing. The differences are not great enough to be significant, but give some indication of a different emphasis in the intelligence of the sexes. Many studies have been made of the intelligence of different races. While the tests show some degrees of consistency, they are probably unfair from the fact that there are differences in the selection of the individuals tested and that language handicaps affect different races. Whites on the whole do better than negroes. The influence of selection or education is seen in the fact that northern negroes test higher than southern. Of the immigrant groups, those long in the country do better than the new arrivals, and the second generation than the first. Final statements of the intelligence of the races cannot as yet be made.

Motor and Temperament Tests

Less progress has been made in devising tests for other aspects of the individual than for intelligence. A battery of mechanical ability tests of all sorts has been developed. These range from simple tests of motor quickness and steadiness, as in rate of tapping and ability to hold a pointer in a small hole without touching the side, to putting together mechanical devices of different degrees of complexity. Most of the tests show a relatively low correlation between mechanical ability and intelligence as measured by any of the tests. A limited amount of intelligence is necessary to understand any problem, but above that the degree of mechanical efficiency has little to do with intelligence. This lack of correlation makes a difficulty for dental colleges since the scientific side of the course is usually taught before the practical. In consequence, not infrequently a student who has done well in the first years finds himself incapable of doing the practical work in the clinical years and must change to another profession. Tests of mechanical ability given to the freshmen have eliminated some men who would have wasted their time if they had gone ahead.

Will and Temperament Tests. — So far no very satisfactory tests of what the popular speech knows as will and emotion or temperament have been developed. That there are differences in these respects too is very evident from chance observation, but the tests that have been suggested have not proved diagnostic when applied in practice. Attempts have been made to rate individuals on these and other general characteristics. One method used has been to form a rating scale in which the raters are asked to think of men who stand for them at different levels in the various capacities, and then to place the man to be rated at the level of the man he most approximates. These methods were used in the army during the war and constituted an advance over the usual undirected estimates. Still there was rather a low correlation between different raters, and all left much to be desired.

Webb's Ratings of Character. — One of the early studies by this method was made by Webb. He asked the masters in an English school to arrange the boys in their charge with reference to certain clearly definable traits. He chose readiness to anger, eagerness for admiration, bodily activity in the pursuit of pleasure, persistence of motives, continuance toward a goal in spite of obstacles, conscientiousness and similar traits for the comparative ratings. The results showed that there was a fairly high correlation between the traits that seemed desirable, such as the persistence of motives that lead toward a remote goal, quick recovery from anger, and conscientiousness. There was also a high correlation between the undesirable group: quickness to anger, eagerness for admiration, and bodily activity in the pursuit of pleasure. There was a negative correlation between traits that belonged to the different groups. The desirable traits had a positive and fairly high correlation with intelligence, and the undesirable a negative correlation with the standing in intelligence tests and in school work. It seems that the individual who is favored in one respect is favored in all. There are few compensations in the distribution of qualities.

The importance of these studies of individual differences is evident from the uses that have been made of them on the practical side. Theoretically, too, it is important to know that men differ and how. We can be said to have made little more than a beginning in the study of these differences but that little is valuable for the methods that have been developed as well as for the results. The studies of intelligence have been developed farthest and are in consequence most fruitful. The beginnings that have been made in other traits have value for the promise of new advances quite as much as for themselves and are not to be disregarded. We shall in the remainder of the book find much material that will be of value in explaining in what the differences we have been dealing with consist, even if that work will for the most part have quite a different end in view.

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CHAPTER VII

THE NATIVE AND THE ACQUIRED IN HUMAN CONDUCT

The Incentives to Action. — As we begin to study human or animal behavior, the difficult problem at once confronts us of deciding what the real determinants of any act may be. If we return to the point of view of the nervous system, we see that one determinant is the stimulus that is affecting the sense organs most strongly at the moment, another the connections that are found in the nervous system between that sense organ and the muscles of the body. If we keep to the simplest cases, the connections between neurones are themselves of two sorts with reference to the way they develop. Certain ones are present at birth, others are formed in the lifetime of the animal. If a new-born babe be stimulated on the lips a series of sucking movements will start. This is especially true if the stimulus applied to the lips be by a soft round object small enough to be taken between the lips. If an electrode be applied to the hand, the hand will be withdrawn; if the stimulus be repeated, the other hand will be brought over to push it away.

Nature and Nurture. — Opposed to the simple connections present at birth, we have a vastly greater number of responses which, although in some part prepared at birth, are also modified through use. A movement may not be made at all by the new-born man or animal at a given stimulus, and then the same stimulus will later evoke a movement. What is far more frequent, one movement will be made in response to a stimulus at first and later the same stimulus will be followed by quite a different response. These different responses become established and will always be made to the same stimulus under the same conditions. Either use or mere growth are assumed to be responsible for the change in the result, and they are generally to be referred to use rather than growth. The two groups, inherited connections and connections developed in some way through use, which we ordinarily call learned, are the causes of the two sorts of responses. Every act is thought of as due to one or the other and most are in some degree an expression of both in different proportions.

Native and Acquired Tendencies Combine. — Modern psychology has shown frequent alternations in opinion as to the relative importance of these two factors. It was assumed before modern psychology developed, that animals were altogether controlled by inherited connections and man was altogether the product of learning. Then there was a period in which the importance of inherited connections in man was given great emphasis. Very recently there has been a swing back to assigning as much as possible to learning and as little as possible to the inherited connections. Each of these extremes is probably an exaggeration of the truth, and each over-emphasis has led to unfortunate results that brought a correction and has resulted in an over-emphasis of the opposite type. In an adult it would be difficult, probably, to find any important act that did not contain elements that had been learned. It is also possible to assert that few acts do not have some phases that are dependent in some degree upon inherited connections, although the proportion of the native elements would be very much smaller than of the acquired. One cannot speak of native and acquired acts and attempt to enumerate each. One can merely indicate how all acts are a resultant of both factors.

The Fixed and the Variable in Animal Responses. — If one takes the simplest case of learning it is possible to show how the original connections and learned ones combine to determine acts and how some process of selection must dominate the whole. If one deals with what is originally a simple reflex or seems to be, a little observation shows that the succeeding responses are seldom quite the same. Even if each act succeeds in some degree in freeing from an unpleasant or bringing near or continuing a pleasant stimulus, those that succeed in greater degree will gradually replace those that succeed in lesser degree. If one goes to a slightly more complicated response such as the pecking of a new-born chick at a grain of wheat, the variation in effectiveness of the different acts is very great, with only 20 per cent or so of completely successful pecks. This increases rapidly over a period of ten days or more to 90 per cent or so. Here the general type of response is innate, but the detailed performance is acquired. In still other types of acts nothing definite seems to be evoked by the original stimulus but a series of vague movements; from these indefinite responses presented as units certain successions are selected that are appropriate to the need of the moment. These acts are repeated with more and more complete approximation to the finally perfected pattern, until they become nearly identical at each repetition. This is true of learning to speak and of all the complicated processes of youth and later life.

The Classification of Movements. — Roughly movements may be divided into three groups as they show tendencies to be more or less definite or perfect at birth. We call those movements, which are simple and have approximately the same form at birth that they have at a later period, reflexes. Those that are absolutely perfect at birth are probably very few. Many others, including the eye-reflexes, are assumed to develop because of the mere growth or ripening of the nervous system without reference to the changes from practice. Intermediate is a group of responses in which the original movements are relatively uncertain, but which through practice reach a well standardized form that is consistent for all members of the species. Pecking and other food-taking movements, including human nursing, are simple acts that fall in this group. Man shows relatively few complicated groups of acts that can be placed in this class. Better instances are provided by the egg-laying responses of insects and the nest building of birds. This group of acts was generally called instinct a few years ago, but objection has been raised to the use of the name or to the real existence of any coördinated series of movements that is assumed to be largely determined by inherited connections. The third largest group is constituted by learned movements.

The Initiating Stimulus. — While these classifications of the completed forms of acts attract most attention, it is more important to consider the factors that lead to the development of all movements. Four simple factors can be selected as effective in the development of any movement. First is the stimulus that initiates the movement. In the altogether perfect reflex this is almost the sole factor to be considered. In all other cases, the initiating stimulus gives rise to a number of movements, both one after the other and simultaneously. The variety is due to the spread of the nerve impulse over different paths. Even perfected habits are accompanied by a number of incidental contractions in muscles, both near to and remote from the main group. The more intense the stimulus the greater the number of these dispersed movements. The degree of diversity in response varies from such a case as wrinkling the brow when drawing a delicate figure to the series of widespread wanderings of startled rat or man in a panic. The variability of response makes possible all learning and all improvement in a movement once established.

Drives to Action. — The determiners of the original activity include not merely the stimuli to the external senses, but a number of internal conditions and stimuli. Most important of these probably is hunger. Thirst, sex, the activity of endocrine glands are all effective. A hungry animal is more active than a sated one. Thirst is nearly as effective in producing responses. A distinction must be made in the forces which induce action between those which contain a suggestion of direction and those which increase the tendency to bodily acts of all kinds. Most of the drives have both effects. Hunger produces a general excitability ; it also impels to movements towards old sources of food, if there has been food presented in the neighborhood. Sex similarly has a general effect owing to the endocrine phase of the secretions, a drive towards general excitability. This is shown in the greater energy of animal with intact gonads as compared with the castrated animal. The bull is more dangerous than the steer. The rooster fights better than the capon, the normal man than the eunuch. Sex also conditions approach to the opposite sex.

Endocrine Glands as Drives. — The other endocrine glands give rise primarily to general excitement rather than to a directed activity. An individual who is deficient in thyroid secretion reacts slowly, is lethargic in the presence of all stimuli. One with excess of thyroid secretion is over active, is 'nervous,' responds with unusual strength to stimuli. An increased adrenal secretion has the same general effect. The activity is unusually pronounced, is increased in intensity and in persistence towards a goal. These two with the sex glands or gonads constitute the most obvious and best known of the endocrine drives. Without them the responses are limited in extent and rather spasmodic. When present the animal responds in the normal way. The drives as a whole are to be distinguished from the external stimuli in that they determine the general effectiveness of the stimulation of the external sense when it occurs. Sight of food that to a sated animal would cause no response arouses great activity in the hungry animal. Slight stimuli are effective in arousing an animal with an overactive thyroid, while intense ones are required to evoke a response in one whose thyroid activity is reduced. Stimulus from outside and stimulus from within, or the endocrine secretions plus the stimulus, are together what may be called the drives to action.

Selection of a Movement to Be Repeated. — The second active factor is the selection of the movement that shall be retained. This factor is probably more definitely innate than any of the others. Objectively the only sign of selection is a tendency to repeat movements that bring results which belong in one class and to avoid repeating movements that bring results of the other class. In the adult human we can see that movements that are repeated are usually accompanied by pleasure, while those obviously avoided are accompanied by displeasure or pain. Even in the adult human it is a question whether the pleasure is ultimate or is merely a name for a general accompaniment of one group of responses. If we keep to the purpose with which we started of giving a perfectly objective description, all that can be said is that if a movement leads to a second stimulus of the pleasant type, that movement will be repeated; if it leads to a stimulus of the unpleasant type, the movement will cease and another movement of withdrawal will take their place. Terminal stimuli of one type may be defined as those which induce movements of approach or continuance of the same movement, those of the other type are such as induce movements of avoidance or withdrawal.

Movements of Acceptance and Movements of Rejection. — These terminal stimuli, then, themselves fall into two classes according to the types of movements which they in turn evoke. They can be illustrated by the eating movements. The young chick at first pecks at most small particles. Pecking is repeated towards objects which when taken into the mouth have a pleasant taste. A pleasant taste may also be defined as one which induces swallowing movements when the substance comes into the mouth. An old experiment of Lloyd Morgan with moor hen chicks illustrates this. He fed them different varieties of caterpillars. Most were swallowed. One sort with a black stripe was at once rejected. After the first trial or two, that variety was not even pecked at. One can define pleasant tastes by saying that they are those which lead to swallowing, unpleasant as those that lead to rejection.

Selection by Terminal Responses. — It is evident that the ultimate explanation of the movement is to be found in this process of selection. If selected, the movement is repeated whenever the stimulus is presented. The variant of any movement that leads to approach or pleasure will be repeated and will become established as the movement invariably connected with that stimulus. It will be learned, if regarded as a new movement; it will be established as an overt reflex or instinctive act, if it is regarded as an inherited movement which at first is not fully developed. The internal stimuli and endocrine secretions are effective in selection, also.

Selection the Real Determiner of Action. — Of the four parts of the completed act, — the response to the initiating stimulus, the variability, the selection, and the learning or establishment through repetition, — the selective factor is the most truly directive and the one that is most definitely inherited or peculiar to the particular species. That certain tastes excite to swallowing, others to rejection is the determining fact in deciding what shall be eaten and in the last analysis that an animal shall eat at all. The same factor determines what shall frighten an animal, what shall arouse sex responses, and so on through the entire list of objects that arouse to action. The problem of action is very closely connected with the reason one stimulus arouses to positive, another to negative responses. If one could answer this question of why a man or animal is pleased by a movement or the results of the movement, one would solve the most important question in connection with why man or an animal acts as he does. All the rest is relatively simple. It is merely that any stimulus arouses to response; the response varies somewhat and sooner or later one of the variations produces a movement or combination of movements that gives satisfaction and for that reason is repeated until established.

The Classification of Terminal Stimuli. — One can prepare a tentative list of those stimuli that tend to induce learning and those which prevent learning or teach avoidance. The animal psychologist finds that foods and sex are positive stimuli and can be used to induce learning, that pain from an electric current or from mechanical stimulation is a negative stimulus and will prevent learning. Different kinds of foods have different degrees of attractiveness. For the hungry white rat food is stronger than sex. For the human, social approval in the form of praise or, on the negative side, blame is a strong factor. Neither for man nor for the animal can an exhaustive list be prepared.

The Inherited Factor in Acceptance and Rejection. — More important is the question why certain stimuli have a positive, others a negative value. Certain of these tendencies must be inherited, as they are present from birth and common to all of the members of the species. Unless we assume that they are native, there would be no starting point for the explanation of learning, simple or complex. The assumption of the evolutionist is that they are persistent in the animal from birth, since if they were not, the animal would not survive. An animal born with a taste for poisons, or a tendency to reject all foods would quickly die of the one or starve to death from lack of food. No one pretends to know what specifically is inherited, although a series of motor connections between sense organs of one sort and the muscles of withdrawal, and between another group of sense organs and the muscles of approach would make a plausible hypothesis. The assumption that there is such a group of inherited satisfiers and irritants is theoretically necessary as a starting point for any theory of learning. It can also be substantiated from observation. Movements of approach to certain stimuli and of withdrawal from others can be detected from birth in both animal and child. If we assume a few primitive likes and dislikes, it is possible to extend them to numerous other objects by chance connections, associations, or what the behaviorists prefer to call conditionings. These will be considered later.

The Development of Pattern Responses. — As the animal or man lives, more and more of these movements become connected into patterns which are run through in approximately the same way in response to similar situations. These then constitute relatively simple organized patterns of responses which are given names, usually with reference to the ends they subserve. Psychology has frequently been content to list the major pattern responses under the name of reflexes, or instincts, or habits. In this listing it has neglected the differences in the patterns of movements, and emphasized the similarities. In many cases only the ends subserved are the same while the movement patterns are greatly varied. It has also overlooked the fact that the differences between the types of movements themselves are less important than the similarities; that after all, the way in which each pattern develops is the same, and that the really determining satisfiers are the same for all types of movement.

Simplest Pattern Responses. — It may be illuminating to give illustrations of different types of native responses, or patterns of response. One of the most perfect pattern responses is shown in the egg-laying of different types of insects. These are specially striking from the fact that they are performed but once in the life of the animal, and so give no opportunity for learning. The female dies soon after laying the eggs and consequently there is no chance for learning or for the offspring to observe the process. An excellent illustration of the pattern response is offered by Fabre, and quoted by Hobhouse as follows: "A solitary wasp, *Sphex flavipennis*, which provisions its nest with small grasshoppers, when it returns to the cell leaves the victim outside, and goes down for a moment to see that all is right. During her absence M. Fabre moved the grasshopper a little. Out came the Sphex, soon found her victim, dragged it to the mouth of the cell, and left it as before. Again and again M. Fabre moved the grasshopper, but every time the Sphex did the same thing, until M. Fabre was tired out."

Inherited Patterns of Response. — An instance of this kind seems best explained by assuming that the pattern is determined by connections which develop in the nervous system of the animal as the nervous system itself develops. The connections between the internal stimulation due to the pressure of the developing eggs, and the external stimulation presented by the prey must combine to produce successive movements in the proper order: to prepare the nest, catch the grasshopper, inspect the nest, put in the grasshopper, lay the egg, and close the nest. Each movement must be excited by the preceding one in the series and by the external stimulus. The whole series is supervised by the stimulus of the developed egg. It is as if there were a mechanism all prepared which needs but the stimuli from within and from without to set it off. The whole series, not merely the satisfying or irritating effect of the stimulus, is prepared by heredity.

Congenital and Delayed Pattern Responses. — As opposed to these series of acts which appear fully formed at birth, or that at least have not a chance to be learned before they are effective, we may oppose the great mass of acts which, if they are in some degree predetermined in the nervous system at birth, need a great deal of development before they reach their final form. We can find these, too, only in animals. Even the egg-laying movements of insects were shown by the Peckhams to be less stereotyped in some respects than Fabre had described them. Although there was no chance for learning, there was deviation in the performance. A kitten killing its first mouse is typical. Berry reported that a kitten had no tendency to kill a mouse that was running about it. The mouse might be running about in the same room with it and not be attacked. A six months old kitten would let a mouse smell its nose without making any attack. Yerkes and Bloomfield tested the reaction of kittens to mice and found a marked difference in the tendency to catch a mouse. One kitten a month old only, before it was yet able to stand and walk securely, seized a mouse by the head and killed it. Others of the same age showed no tendency to seize and kill. Each of eight in two litters did spontaneously develop the killing response. The attack was evoked most certainly at first by a rapid running of the mouse. Later the odor of the mouse sufficed to start the hunt.

The only sign of pattern reaction in the attack was a tendency to seize the mouse by the head or front part of the back, which prevented it from biting, and the crouching and stalking movements which preceded or initiated the attack. As the kittens grew older there was an increasing tendency for the kitten to play with the mouse before killing it. The play was not sufficiently definite in form to constitute a restricted pattern, but did enter into a variable pattern. The most striking results of the experiment were the delay in the appearance of the killing response and the different age at which this response showed itself in the different individuals. The variation was from one to nearly three months. The fact of delay is of great importance in the theoretical explanation of inherited responses. If a response can be made perfectly on the first trial some months after birth and has not been made earlier, it seems probable that a definite stage in the growth of muscular mechanism and of nervous connections may be necessary, and that pattern responses may be delayed and still be inherited. Yerkes suggested that if a delay in applying the stimulus to the act was too great, the tendency to respond might be lost. James had also made the suggestion on theoretical grounds. Yerkes explained Berry's six months old kittens letting the mice play with them without attacking as due to the loss of the inherited tendency. This would be a case of a relatively indefinite pattern response evoked by a stimulus which appeals at one age and not at another. The tests were too few to determine whether there was improvement in the acts involved in killing.

Pecking Response as Delayed. — Pecking in chicks affords an opportunity to study the progress of a movement, present from the beginning. Breed and later Shepard and Breed tested the effect of mere growth as compared with growth plus practice upon accuracy of pecking. With new-born chicks records were kept of the number of hits made on successive days under normal conditions by one group. Another group of chicks was kept in the dark and fed by poking the food into the bills so that no practice in pecking could be had. These chicks were tested after delays of from two to five days. The two days' old chicks made but 20 per cent of hits the first day, and this percentage increased regularly to 80 per cent in the course of eight days. The chicks that had been kept in the dark for different periods also made about 20 per cent hits the first day of practice. That their capacity had increased through growth without practice was proved by the fact that they made very much more progress than the younger chicks and were making 80 per cent hits also by the eighth day of life. The pattern is partly the result of mere growth, but is mainly due to practice.

Loss of Inherited Tendency with Disuse. — Padilla, who repeated the experiments, obtained a second result by delaying for a longer period the beginning of the training experiments with older chicks. This confirmed the suggestion of Yerkes and others that native tendencies will be lost if not exercised early enough. Some chicks were not permitted to peck or even to see until eighteen days old. These chicks when put in the light and given grain made no attempt to peck. When left to themselves in the midst of plenty some actually starved to death. Some were taught to peck after they had made no attempt of themselves by moving the grain, and by having it put into their bills. At first they would merely swallow when it was put into their throats. Gradually they passed from this to pecking of themselves. Obviously something is inherited that requires use to be retained and to be brought to full strength of function. This something that is inherited may be the nervous connections that are required in a pattern response. It may be only the tendency to make indefinite movements upon stimulation or upon stimulation of a definite sort. It may be the tendency to repeat responses that give rise to effects that are satisfying. Possibly it may be merely the tendency to be satisfied by one effect and be annoyed by others.

The Innate Human Action-Patterns. — The problem of how much of human action or conduct is determined by heredity and how much is due to learning alone may be approached in much the same way. The human infant at birth offers fewer specific reactions and is much more helpless than the animal. It is probably safe to assert that man shows no single pattern reaction, aside possibly from the nursing response. Frau Bühler reports that during the first three months the human infant shows mainly negative responses to stimuli. The only positive reactions are to warmth, as of the mother's body, and to food. It withdraws from stimuli, struggles to free itself from restricting clothing, draws together when excited by a bright light or loud sound, cries. These constitute the sum-total of activities of the child during these early weeks. Watson showed by experiment that the new-born child will grasp a support presented to it, and can support its own weight. Darwin had demonstrated this act and placed much emphasis upon it as evidence of evolution. He argued that the tree-dwelling ancestors would need to be capable of supporting their weight from a branch, if they were to escape early destruction from a fall, and that this supporting reflex has persisted in man although now useless. This movement is hardly more than a reflex taken apart from its purpose, but the reference to the past has given it an interest which mere grasping a bar of the crib with one hand lacks.

How First Human Acts Are Determined. — If we eliminate pattern responses from consideration in connection with man's conduct, the only inherited factors left are the processes that select the chance responses. The infant exhibits two types of movements from which develop the acts which are to constitute its armory of systematic responses: the forced reactions to stimuli and spontaneous movements. Again, according to Bühler, the new-born infant exhibits ten times as many forced movements as spontaneous ones, the one year old infant spends twice as much time in spontaneous movements as in forced ones. Probably the spontaneous movements also are reactions to stimuli, internal and external, which the observer fails to notice. The distinction is important in this connection only because the spontaneous movements offer a greater variety and so give a greater opportunity for the establishment of reaction patterns. What gives real direction to the development of acts are the factors that evoke repetition. These are the pleasures and pains to use the words of everyday life and of the traditional psychology. These words have been used so long that they have undesirable connotations for some schools and may be replaced by the terms *satisfiers* and *annoyers*. Some prefer the word *motives*, but motive implies a determiner of action and in dealing with these first acts what matters is merely that the results of the act once made shall lead to its repetition. After the act has been performed a sufficient number of times, the total group of older experiences connected with the act consolidate into what is really the motive.

Innate Determiners of Human Action. — For the new-born infant, only taste and warmth are positive determiners. To the pleasant tastes, which alone are presented to the child under natural conditions, he reacts by swallowing. The reaction to warmth is to approach the warm object and to relax. Pains of all sorts arouse withdrawal and, when continued or repeated, intense crying. Tastes which are unpleasant evoke rejection movements and also characteristic facial expressions. In the case of the new-born infant one is struck by the small number of stimuli which produce either positive or negative reactions and also by the poverty of reactions. Classification of the stimuli which have a preëmptive value in evoking responses would include foods, a few odors, strong stimuli of all senses save at first possibly sight. As the infant grows older the number of these preëmptive stimuli increases slowly at first, then more quickly. By the second month moving objects seen are effective in holding the eye. Responses to people come relatively early. Smiles bring responses of appropriate expressions from three months on. Even in the first month another child's crying will start a crying period. Before the end of the first year the presence of another child will initiate movements of approach.

Imitative Movements. — What develops is the number of stimuli which will call out responses, the characteristics of the responses, and the tendency of the effects of stimuli to satisfy or tend to be repeated. Sounds of the mother's voice attract relatively early, but it is only after two months or so that the child will make sounds of its own, and tends to repeat them when they chance to resemble the sounds he hears. Imitation of movements comes by the third month. Imitation of movements of the forearm begins gradually, then increases for three months or so, and then gradually decreases. Here again, emphasis must be put upon the appeal of the stimulus not on the movement. Before three months little attention is paid to the movement of an adult in the first place, and in the second place when his own members repeat the movement no notice is taken of it and so it is not repeated. The various tendencies to imitate appear at different periods, arm movements at three months, head movements at five, wrinkling the brow at nine. Each increases gradually to a maximum and then disappears as if the child lost interest.

Classification of Preëmptive Stimuli. — When one attempts to classify the innate characteristics of the individual, one must deal with the types of stimuli that evoke and lead to the repetition of movements, rather than with the types of movements themselves. Aside from simple withdrawal movements, the shrinking at strong stimuli, weeping and nursing, there are no innate pattern responses. On the other hand a vast number of stimuli do have a preferred place in evoking responses and in leading to the repetition of them once they have been made. The stimuli that appeal are those that are important for the well-being or ill-being of the individual. Foods or poisons or tastes that are similar to noxious substances fall into this list. Withdrawal of support also appears early to produce a response. Beyond this with the growing development comes the appeal of various stimuli which are not important for the survival or even well-being of the civilized man but which may be regarded as having been essential to the survival of primitive man. Here would come interest in the chase, in personal combat, possibly in construction, and numerous others. There is no definite reaction pattern that the man shows when following the fox, but the enjoyment in the chase is greater than can be explained from the open air or delight in rapid motion.

Fears. — The same dominance of the stimulus as opposed to the reaction can be seen in fear. It has frequently been asserted that two types of response are evident in fear. One is marked by numerous diffuse and insistent movements, the other by the cessation of all movements. The first may be seen in the paramecium on a slide heated to 55° C. and in a man in a theater panic. The paralysis has been demonstrated in the 'walking stick' by Holmes. When thrown roughly upon the table the 'walking stick' becomes immobile for a time. Better known but of the same character is the so-called death feigning instinct of the opossum. The loss of power of a man in a panic belongs in the same class. Either of these responses or both in succession may be seen in the child or in the man. More characteristic are the changes in the unstriped muscles and glands, which, since they are most evident to the man who is afraid, are considered under emotions.

What stimuli shall excite these responses seem also largely determined by inheritance. In some cases they may be modified or transferred by experience, but not explained originally by it. Why a grown woman should be so startled by a mouse, why a man should make such exaggerated responses when a harmless snake wraps itself around his ankle, are hard to understand in the light of experience alone. Similar are the trembling at looking over the edge of a precipice from behind a perfectly secure railing, the fear of the dark, of caves and strange places, of the dead, and hosts of others that the reader may supply from his own experience. In the development of a child, these fears come one after another and frequently disappear almost as suddenly as they appear. Interesting, too, it is to note the tendency of those fears to become exaggerated in diseased conditions of the central nervous system. Here we find fear of open places that leads the victim to slink around the sides of parks rather than walk across them (agoraphobia), and also, the opposite tendency, to fear all closed places, to avoid rooms and narrow streets, and to feel at home only in the open (claustrophobia). These are but two of many morbid fears.

Curiosity. — Curiosity shows even more clearly the dominance of the preëmptive stimulus over the pattern reaction. Any new stimulus brings out the exploring movements in the infant from five months or so on. The dog, the cat in less degree, monkeys in the extreme, show a tendency to examine all strange objects. From their acts one might argue that they were intent on understanding them. Certainly in man there is a pervading restlessness until all unfamiliar objects and movements have been examined and explained, — an instinct that shows itself early and persists with increasing intensity until well into old age. In its simple forms in the child or in the uncultivated it impels an investigation of all possible sources of danger and provides for the security of the individual. In its higher forms it may well be regarded as the source of very much of man's desire for knowledge and of the growth of science developed from it. Much of this knowledge is probably useless from the practical man's standpoint, and in any case the investigations that lead to the discoveries are most frequently carried out for the sake of the knowledge itself, rather than from any intention of obtaining practical benefit.

Social Responses. — Much discussed has been the problem as to whether man as an individual or in the mass has a special appeal or arouses special forms of response in other men. On the whole the sociologist and social psychologist incline to the view that little or nothing is inherited in the way of social responses and social attitudes, but that all of the influences that other men exert upon us arise from the benefits and injuries actually experienced from people in the past and expected in the future. Part of this is due to the established fact that there are no inherited pattern reactions towards people. The responses evoked by them are different on each occasion. On the other hand Frau Bühler's studies show that the child is very early especially attracted by adults and other children, that this interest develops increasing strength during the life of the child. Of course the fact that the child receives food and all care from persons would explain this in part. That this is not all is rendered probable by the fact that interest in other humans shows itself when the child is not specially in need of food or other attentions almost as markedly as when these needs are strong. The great strength of the feelings aroused by people also is opposed to this view. Frequently the appeal of the social is much greater than of food or pain. It also shows itself under circumstances in which no advantage of another type is likely to accrue. Of course all the appeals of stimuli that appear after the first few weeks are colored by experience, but granting this fact it is probable that people have an especial attraction, that the social is a preëmptive stimulus.

Gregariousness. — Whatever their origin, the various effects of other people upon the individual are sufficiently important in practice to make them worthy of notice. The simplest of these is the mere pleasure in the presence of other people, which Galton called gregariousness. This is shown in its purest form in the lower animals, but is not without its analogues in man. The bison or reindeer or the wolf, under certain circumstances, seems to feel pleasure in merely being with others of his species. The same force may be seen in men who feel pleasure in being in the crowd on a city street, even if there be no words spoken and no intercourse of any kind with the members of the crowd. One may be absolutely alone, even avoid conversation with his fellows, and at the same time feel pleasure at their presence, or at least feel a haunting and unconquerable loneliness when away in the wilderness or where his fellows are not to be found. Obviously this attitude finds no simple expression in action, but is due merely to the pleasant feeling of being with others or to the unpleasantness of being alone. The individual may and usually does definitely plan the movements that will take him to a place where people are likely to be found, but the tendency to dwell fondly upon the idea is inherited, as is also the restlessness that may persist without awareness of its cause until other human beings chance to come.

Sympathy. — More active is the immediate response of displeasure at the sight of suffering in another man especially, and even in an animal. For it we use the Greek word *sympathy*, meaning literally 'suffering with.' Some of the response in this case seems directly physical, a loss of strength, pallor, in extreme cases vomiting or loss of consciousness at sight of bleeding or intense pain in another. Sympathy prevents cruelty on our own part and enforces giving aid to those who suffer at the hands of others or as the result of natural forces. It can be seen in the gregarious animals who exert themselves and even suffer in behalf of the herd, as the male deer are said to form a circle about the females and the young and to risk their own lives in defense of the unit. This instinct may be justified teleologically, since the survival of the individual and especially of the race depends upon the survival of the larger group. In man the most striking feature of the instinct is the limitation put upon the group included in its manifestations. It may and has been regarded as an extension of the racial appeal, the desire to protect the young, but it includes, with a force that diminishes with its extension, an ever-widening group of individuals. The members of the particular social set stand next to the family, then the individuals of the same class. The further extensions may include the ever-widening circle of political divisions, it may be drawn in some degree in terms of religious or party affiliations, — in fact, any common belief or common purpose may serve as the bond of union within which the instinct of sympathy may act. In these divisions any common ideal, particularly any common ideal that has opponents, may serve as the basis for the organization of a group within which the bonds of sympathy are effective against all outside it.

Submission and Aggression. — McDougall asserts that in every individual there are present opposed tendencies towards other individuals or to man in the mass. One is the tendency to be dominated by others, the other is the tendency to dominate others. The first is present in all individuals at some time, the other is rarer and is specially prominent in some individuals. Submission shows itself first in fear of strangers which as bashfulness makes its appearance in early youth. This persists with varying periods of increase and decrease throughout life. This milder first form of fear as seen in bashfulness becomes in its more general expression the means of social discipline that makes possible action in the group. It can be seen first in the direct repressing influence of the group when physically present upon all but the leader, and on him it acts more strongly than he is willing to admit. One rises with fear, if at all, to protest against any action of a crowd. Unless experienced, a man shows many signs of fear as he addresses an unfamiliar, even if friendly, audience.

Social Pressure. — The wider influence of the effects of this fear of social disapproval and pleasure in social approval can be seen everywhere in social affairs, and in many fields which are not usually recognized as social. Cooley called it social pressure. It is, without our being aware of it, what gives vital force to most ideals, religious and moral; and which compels us to follow styles in thought as well as in dress. One feels uncomfortable when clad in last year's gown, as one does when admitting adherence to an unpopular political party or to a generally condemned social theory. This is the real social pressure which compels conformity in every field. As an active force it drives the individual in much of his effort to get ahead. It keeps the student attentive to an uninteresting lesson and it impels the laborer or business man to long hours of labor that shall enable him and his family to keep up appearances in their own social set or in that to which they aspire. These influences hold the man to his accepted place, keep him to his allotted task in moments of weariness, prevent eccentric acts and remarks, are the forces that make society possible, even if in very many cases they make convention dominate originality. In the individual they serve as spurs to many of the activities with a more remote purpose; they give the ideal and unselfish aim an approximation to equal standing with the material and the selfish.

Racial Appeals. — Equally strong and different in their effects are stimuli which appeal because of their value for the survival of the race. These appear in full strength only with the ripening of the sex glands although social and other associates earlier may make them more attractive than the ordinary stimulus. The appeal of the girl to the boy may be different from the appeal of another boy from a fairly early age, but this is probably in part due to social training. The difference may be either positive or negative. Some boys from a relatively early age seem to be negatively affected by the girl, to be interested only because of her strangeness and because of the mystery which generally attaches to sex, but to avoid rather than to seek her companionship. With the development of the sex glands, this undergoes a gradual change. The avoidance on the part of the bashful youth may continue, but there is a specifically different appeal. The secretions of the gonads act upon the sensory as well as the motor processes to make objects interesting that had previously been largely ignored. Feminine outlines that up to that time either had not been noticed or aroused only an æsthetic interest now excite emotions of a warmth hitherto unknown.

Few Pattern Responses in Sex Life. — Here as elsewhere in man, the responses that result do not fall into patterns. While the feeling reaction may be approximately the same in different individuals, the responses vary widely. The young male in the presence of the object of his adoration may be boastful and given to display, or he may be awkward and inhibited in all of his movements. The specific courting acts vary with the conventions of his set and the circumstances. Even more widespread in their effect upon society are the activities and feelings involved in the care of the young and in keeping together the family. In man these processes are largely indefinite. They are guided by the pleasure of the parent in the welfare of the child. Most of the actual movements are learned through education and developed by habit. Only the pleasure produced by the achievement of the end and by the presence of the child is really instinctive; the rest is habit. In the lower animals of course the instincts are much more definite, as in the building of the nest, in determining the kind of food that is given, and the way it shall be given. Even here, however, much is left to the control of circumstances, for the processes cannot be reduced to a mere chain of reflexes. In man the continuous association and the care for the welfare of the members of the family constitute an important element in the development of unselfishness in general and of all the ideal elements in character.

The Problem of Instincts. — We have been discussing in this chapter the problem that is usually called instinct. We have carefully avoided the term because while the problem is vital, the word instinct has been used so loosely that it has picked up many unfortunate associates. The word *instinct* was traditionally used to mean a response made up of a series of separate movements joined together and to the stimulus that evoked them by a series of connections in the nervous system. In practice most writers have used the term to describe movements that are vague rather than definite, in which what is inherited is not a series of sensori-motor connections but a mere tendency to regard certain ends or certain stimuli as desirable. We have found in the lower animals a few pattern reactions, in man none, probably very few are present in the mammals. In place of this we see that the most that is inherited is a tendency to accept and attempt to obtain again certain results which were at first the product of undetermined movements.

Alternatives of Instinct. — Various suggestions have been offered as to how the facts can be squared with the nomenclature. Watson denies instinct altogether and asserts that an animal learns everything. This does not recognize the fact that certain ends are attained in preference to others nor the great liking for certain stimuli as shown by their tendency to induce repetition and learning. Again emphasis has been put upon the increased accuracy in pecking movements after a few days' growth. This suggests that connections may exist which do not reveal themselves in movements at once after birth, but which do make certain movements easier to learn than others. These have been called delayed instincts. Allport has called them prepotent habits. This phrase makes recognition of one phase of the facts. It is possibly unfortunate in that it emphasizes the purely motor side of the problem and neglects the facts that the preëmptive stimulus and the feeling processes which determine repetition really select most of the movements that develop. In the prevailing confusion it is probably best not to use the term *instinct* at all or to use it only with a vague meaning. Instead we can speak of the pattern reactions which are present in the invertebrates, and of preëmptive stimuli or of inherited feelings when we consider the inherited factors in human action.

The Classification of Innate Responses. — It is also not wise to speak of separate instincts whether we use the term as pattern reaction or as innate affective response. To speak of an instinct of acquisitiveness, *e.g.*, seems to imply and is frequently taken to mean that there is a series of responses involved which presuppose an entity of some kind behind them, — that this something persists and is inherited. No one means this when stated explicitly. The most that could be meant by acquisitiveness is that what is inherited and what is learned emphasize the desirability of having reserve resources. This knowledge and the desires that arise from it, together with vague inherited dispositions, make most men react in very much the same way to any object of value. Any classification can refer only to general ends, not to patterns of response. We have grouped them tentatively in terms of the main ends that are fulfilled by all acts, protection of the individual, responses towards other men or to society, and responses that further the continuance of the race. These classes are not sharply marked off from one another, for the same act may further all three ends. The ends also are not conscious at the moment of the act. The classification is only a rough one made to name the total effect after the acts have been performed. It does not imply a series of unit forces which are inherited and drive the man to specific acts.

The Origin of Innate Tendencies. — The problem of how the race develops a tendency to perform pattern reactions or to be pleased by a particular stimulus takes us into biology.

Both must depend upon changes in the connections in the nervous system. These connections must develop by chance and then be inherited. It is but one phase of the general problem of evolution. If we accept the doctrine that structures develop by the action of definite forces on the germ plasm, and that those variations which make for survival persist, and those that are unsuited for survival cause the animal to die and eliminate the variation, the same principle would apply to the connections which make possible the use of the members. It is just as necessary to have the nervous connections develop which operate the member as it is to have the member. Pattern reactions depend upon definite connections in the nervous system. Without knowing the specific method by which they may have developed or been transmitted, one could picture them as dependent upon definite genes which determine the direction of growth of the axones.

The determination of certain responses or certain stimuli as pleasant may also be related to the development of connections. We have seen that a characteristic of pleasant stimuli is that they evoke responses of approach, while the unpleasant call out movements of withdrawal. These connections would be as easily inherited as those involved in pattern reactions. We must consider the theories of pleasure and pain in the next chapter. Whatever the theory, the feeling must have a physical correlate. This physical aspect would originate by variation and be inherited in the same way as any structure. For all evolution the assumption is that change in the germ plasm causes the variation. It is known that external forces like the X-rays working on the germ cell will produce variations in the structure of the descendants. What forces produce these changes and whether they are chemical or physical or both, no one pretends to know. Suffice it to be certain that they are produced and that once produced natural selection consists in having those animals with one sort of variation live and those that develop other sorts of changes die. This explains the development and persistence of pattern reactions and also the preëmptive character of certain stimuli, and the feelings that attach to them and to the results of certain actions.

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CHAPTER VIII

FEELING AS SELECTIVE AGENT AND AS PHASE OF CONSCIOUSNESS

IN the last chapter it has been emphasized that almost all behavior, both human and animal, is determined in last analysis by the predilection of the individual for one stimulus or for one result as opposed to others. Obviously the fundamental problem of behavior cannot be solved until we determine as nearly as may be in what this predilection consists. In man we see that the selection is closely connected with what we call pleasant and unpleasant, liking and dislike. If a man samples a new dish and as it comes into his mouth he makes a wry face and spits it out, he will tell you, if you are simple enough to ask him why, that it is unpleasant. He may go farther and say it is nasty or use any one of the dozens of condemnatory adjectives that may be applied to food. If you are dealing with the choice of a cravat, the expressions and motor processes may be lacking. Still the decision will be made on the basis of the pleasantness or unpleasantness of the color combinations. Choice of everything from food, throughout the range of sensory stimuli to friends and even of logical conclusions, is colored by what we call feeling tone.

Mutual Relations of Feeling and Response. — When we were dealing in the last chapter with acts, we used feeling as the determining factor in the selection of one act rather than of another. When we try to answer our present question as to what is pleasure or what gives rise to it we are tempted to reverse the process and assert that it is a state marked by movements of approach, if pleasant, and by movements of withdrawal if unpleasant. We can tell from the acts of the man that he is violently pleased or displeased. It is possible to define the pleasant stimuli as those that cause movements of approach or retention; to define unpleasant stimuli as those which cause movements of withdrawal or rejection of the stimulus. The pleasant is that which we approach, we approach that which is pleasant. Both are true, but when put together, the question becomes which statement is more fundamental, or is there evidence that either statement or fact can be connected with something else that explains why both are true. Each has been used by distinguished writers as the explanation of the other, so that appeal to authority does not help.

We can make a formal reference to connections in the nervous system to explain the response. It is merely that there is a close synaptic connection between a given form of stimulation and the motor nerves that leads to withdrawal or approach. The explanation is limited in its usefulness for our purpose by the fact that the movements which we need feeling to explain are those which are not simple reflexes, but those which are tentative and succeed only after several trials in becoming established. It was indicated in the last chapter that it might be, not the primary response but the secondary, that was determining in that case. In the case of eating it was not the movement of taking the food into the mouth, which might apply alike to all objects of a certain size, but the reaction of swallowing or rejection after the food was in the mouth which determined the pleasantness or the reverse. It is not the chance movements which constitute crawling under the blanket, that conduce to pleasure, but the relaxation and snuggling under that follows which are the determiners of pleasure.

In addition to these movements which are specifically connected with the stimulus there have been attempts made to suggest that other incidental movements may be responsible for feeling. With the rejection of food there goes a wry face, a characteristic contraction of muscles about the mouth which Wundt says is different for each of the principal tastes. These are on the whole different in pleasure and in displeasure. Slighter and greater movements have also been enumerated. Changes in circulation and respiration have been studied exhaustively, so exhaustively that we shall need to treat them separately. A contraction of the pupil is always present in pain and in extreme pleasure. More related to our original proposition is the observation that if a record is made of the movements of a freely swinging arm, it is found that there are in general movements of expansion in pleasure and of withdrawal or drawing together in unpleasantness. These facts show merely that movements accompany all experiences of pleasantness and unpleasantness; they do not indicate, however, how or why we select the larger bodily movements that are accompanied by the characteristic lesser movements. We may later raise the question of the relation between these movements and the qualities that are experienced. There seems to be nothing in the slight movements that accompany the main ones to explain why these latter should be repeated or checked in their repetition.

We are left then with the empirical fact that movements in any way connected with pleasure tend to induce repetitions. This has been observed so frequently and is so universally true that we have an 'of course' attitude towards it which seems to make explanation unnecessary. We could of course speak of a retroactive dynamogenic effect of the feeling that makes all movements accompanied by pleasure seem important, but this is no more than giving a high sounding name to the observed simple fact; it does not explain it. Even if we attempted a neurological explanation and should assert that the movements accompanying the process we call pleasant caused a retroactive spread of impulses across the synapses of the neurones that acted together in the original movement, we would be building unconfirmed neurological hypotheses that put us little farther ahead than our original observed fact. We apparently must be satisfied with our first statement that the experience we call pleasant is closely associated with the habit formation process and that it seems on the whole to be more primitive than the motor phases of the act that it cements into a unitary pattern.

FEELING AS CONSCIOUS PROCESS

The purely objective or behavioristic side of feeling leaves us with the bare fact of its dominant position as the determiner of most acts and as the one innately determined human process. The other side, the feeling processes as conscious states, has a longer history and supplements the purely functional aspect. The term feeling has been used in psychology at various times in many different ways, as the equivalent of sensation, and to designate many of the less definite mental processes, a feeling of recognition, a feeling of belief, and so forth. However, technical psychological usage has settled upon *affection* as the term to designate the pair of opposed processes that we have been calling pleasure and pain. In this usage affection as an aspect of consciousness is put upon the same level as sensation. It is immediately given, cannot be described, and cannot be analyzed or reduced to something else. Since sensation and affection are the two fundamental aspects of consciousness, we shall need to distinguish them. They must be distinguished in two different ways. First, as sensation and affection are evoked by the same stimulus, and so are always found together in time, it is convenient to be able to distinguish them. In the second place, after we have them distinguished we must determine their differences.

Affection and Sensation. — Since the bare feeling is never found alone but is always accompanied by sensation, it is necessary to distinguish the simple element from the complex of sensation and feeling. Thus, in a headache there is a definitely localized sensation or mass of sensations, and in addition we dislike the ache. The dislike itself, or the form that it takes as a mental process, is the affection, the unpleasantness. No one would deny that this is quite different as a conscious quality from the sensation itself. This quality with its opposite is what is defined as *affection*. The complex of affection with sensation is known as a *feeling*. Psychologists thus distinguish affection from feeling for their technical usage. Affection is the bare fact that we find an event pleasant or unpleasant, while feeling is used to indicate the complex of sensation and affection. Thus, in the instance above, the mere unpleasantness of the experience connected with the headache is the affection, while feeling is the term applied to the total experience. What is meant by this state can be understood by all, but can be accurately defined or described by no one. Sensations or affections are said to be the elements of consciousness, but that does not mean that they are ever found separately. All that is meant is that it is possible to discover in mental states a sensational phase and an affective phase, — that certain states are similar by virtue of the fact that they are pleasant, just as certain others are similar by virtue of the fact that they are green, and still others in that they are square. For convenience, then, we have spoken of sensations as independent existences and shall speak of affections in somewhat the same way, as if affections were elementary conscious states, and that mental states might be compounded out of them as substances are compounded out of chemical elements. We may follow the general plan in studying affection that has already been used for sensation, although the approach is less direct.

AFFECTION

Affection and Sensation. — In justifying a separate discussion of the affective phase of consciousness, we must meet two objections. First, it has been held that feeling is only a special kind of sensation; second, that affection is not a distinct element at all but merely an attribute or accompaniment of sensation.

Affection Not a Special Kind of Sensation. — In answer to the first position it should be pointed out that affections are unlike sensations in that they have no special sense organs. Pleasure may come as the result of the stimulation of any sense organ, and displeasure similarly may be the accompaniment of many different kinds of stimulations and may be excited through many different sense organs. The argument for the specific sensations of pleasantness and unpleasantness seems to have been developed on the assumption that pain and unpleasantness are identical. As we have seen, there is a special sense organ for pain in the skin and other tissues, and if pain and unpleasantness are to be considered identical, the sense organ for both is readily supplied. As a matter of fact pain and unpleasantness do not mean the same thing. Pain is the specific sensation, and unpleasantness the accompanying reaction. One may see this most clearly, perhaps, from the fact that pain is not necessarily unpleasant. Without speculating as to the pleasure of martyrs, or the abnormal pleasures of masochism, we find numerous cases in which slight stimulation of pain spots is pleasant, as in the cold of a bath, or the fascination of pressing gently upon an inflamed spot. While pain in slight intensity may on occasion be pleasant, it is not at all infrequent for unpleasantness to accompany other mental processes in which there is no excitation of a pain nerve. Smells are unpleasant when there is often none of the sharpness that represents the excitation of cutaneous sense ends. The odor of decaying flesh is unpleasant in itself, as opposed to the unpleasantness of ammonia or chlorine, which is in part due to the excitation of pain nerves in the mucous membranes of the nasal passages. Unpleasant combinations of colors or of tones belong in the class of experiences unpleasant in themselves, as do also the unpleasant effects derived from unpleasant spatial and temporal relations, the unpleasant ideas from social wrongs, etc. One finds a long list of unpleasantnesses that cannot be referred to sense pains.

If pain be not identical with unpleasantness, and the pain nerve be not the organ of the unpleasant affection, still less is it possible to find a specific sense organ for pleasantness. It has been suggested that tickle may be the pleasant quality, and that there is a specific sense organ of tickle. This latter statement, however, is very questionable. Tickle spots have now and again been reported, but the report has seldom been confirmed, and has never been generally accepted. Granted the existence of the tickle spots, the same objections hold to identifying tickle with pleasure as to identifying pain with unpleasantness. Tickling may be unpleasant and many different kinds of pleasure have no resemblance to tickling. Evidently even if we grant the existence of the tickle spots, pleasure must be something more than a peculiar cutaneous sensation, just as unpleasantness is distinct from and in addition to pain.

Affection Is Not Localized. — Other objections to identifying affection with sensation may be made on the basis of the lack of accuracy of localization of the affections. Sensation always has a definite place, while affection is not definitely localized. One is displeased or pleased in no particular part. Exceptions have been taken on the basis of organic sensations, but organic sensations are rather incorrectly localized than unlocalized. Another distinction, which rests on a slightly less certain basis but is probably generally valid, is that sensory processes are more objective while the affective processes are more subjective. Sensations usually are referred to the outside world, while feelings are peculiarly personal, peculiarly one's own.

Affection and Attention. — Closely related to this are the differences with reference to the effects of attention and the influence of recall. It seems fairly well assured that attending to a feeling tends to diminish rather than to increase it, while, as was seen, attention increases the effectiveness of sensations. In passing upon this statement, one should be careful to distinguish between attending to the stimulus or to the sensation, and to the mere accompanying pleasantness or unpleasantness. If one thinks of an aching tooth, the pain is increased and the accompanying unpleasantness with it. If, however, one attempts to introspect, to ask how and why this sensation is unpleasant, one will be likely to find that the unpleasantness diminishes as one becomes interested in watching the feeling, and it may disappear altogether. An unpleasant situation bravely faced tends to lose much of its unpleasantness. The same may be said of pleasantness. In practice, a constant search for pleasure defeats its end. A pleasure attended to tends to diminish. Lives spent in pleasure-seeking seem never to attain their goal. The only way to make sure of pleasure is to keep in mind some end to be accomplished and let the pleasure come as an incident to its attainment. Keeping pleasure itself in mind destroys it, while attending to the stimulus increases pleasure as well as the sensation. The objective and subjective difference may be said to be one phase of this influence of attention. Objective processes, when attended to, increase; while a purely subjective process, particularly if that be related in some way to attention itself, would not be increased. If one think of feeling as an effect of attending to a stimulus, it would follow that when attention was not fixed upon a stimulus, at least one condition of feeling would disappear, and the feeling with it.

An Affection Is Not Recalled. — This subjective character of feeling has also been connected with another character or alleged character of feeling, namely, that it cannot be remembered. It is asserted with some warrant from observation that feelings are not recalled. This statement must be carefully guarded and restricted if it is to be accepted. The warrant for it is to be found in the fact that feelings toward an event are likely to change between the time the event is experienced and the time it is recalled. Thus a social *faux pas* that caused extreme embarrassment may later arouse only amusement, and a practical joke that was much enjoyed at the time may be recalled with chagrin. The affection alone is not recalled in these cases, but the event is recalled, and the feeling aroused depends upon the circumstances at the moment of recall. This does not mean that one cannot remember that one was pleased or displeased on the first occasion; one remembers the fact, but the affection is not reinstated. The memory of how one felt is indirect, is in terms of words or of the memory of the expression. The feelings are not reinstated as the sensory elements may be, but are merely represented or meant. The feeling at the time of recall is the expression of the present attitude toward the event rather than of the earlier attitude, the attitude when the event was really experienced.

Altogether there seems little probability that affections are merely separate sensations. Pain and unpleasantness are distinct, and pain seems to be the only sensation which could in any degree be confused with either pleasantness or unpleasantness. Pleasant sensations have no existence; *i.e.*, there are no sensations to which the term pleasantness could always and regularly be applied that do not have a distinct sensation quality in addition. To assume that any of these sensations could be regarded as identical with the feeling qualities is out of harmony with the facts of distribution, as well as with the qualities of both sensation and feeling. The more definitely qualitative differences, the different influence of attention, and the difference in the way they are affected in recall, all reënforce this conclusion.

Affection Not an Attribute of Sensation. — The second position in criticizing the separation of affection from sensation — that affection may be an attribute of sensation — meets with just as grave difficulties. As Külpe has suggested, it is always true of attributes that when one vanishes or is reduced to zero, the sensation also disappears. Sensations with no affective tone are, on the contrary, relatively common. A sensation may be indifferent and still be a sensation, while a sensation that has no quality and no intensity ceases to exist. Furthermore, affections have attributes of their own which vary independently of the attributes of sensation, which again is inconsistent with the assumption that affection is merely an attribute of sensation. Affection has duration, intensity, and quality, is unpleasant or pleasant, although it has no extent or position. On the affirmative side of the question, it must be granted that we apparently never have affection without some sensation, and so it is not an entirely independent entity. One never feels vaguely pleased or displeased: there is always some sensation as the occasion for the affection. In certain instances the affection seems the dominant element in consciousness, but slight observation indicates that there are also sensations, usually of a vague organic character, that serve as the excitant of the feeling. But, as has just been said, this same sensation may at times be present in some degree without any accompanying feeling or, on occasion, with a feeling of the opposite character. On the whole, it seems fairly safe to conclude that the qualities of pleasantness and unpleasantness are found in close dependence upon stimulus and sensation, but nevertheless constitute what may be regarded as an independent mental state, or, to speak more conservatively, as a phase of consciousness which cannot be understood if we regard it as merely sensation, or as an attribute of sensation.

Treating our topic from the structural point of view, affection constitutes a type of mental process distinct from sensation but nevertheless dependent for its existence upon sensation, certainly upon the excitations that cause sensations. Pleasantness and unpleasantness come as a result of sensory excitation immediate or recalled, and these excitations produce sensations at the same time or a little before they give rise to the affections. It is probably true that no excitation gives rise to an affection without also arousing a sensation. The occasional periods of vague well-being or vague ill-being without apparent sensational basis are rare, and in all probability are merely cases in which the affective aspect of consciousness has for the moment overshadowed the sensory. While affection is thus dependent upon the same excitations as sensations and even probably dependent upon the sensations themselves for its existence, it is not a mere attribute or phase of the sensation, as are quality and intensity; rather we must regard it as a separate mental state or process with attributes of its own.

Qualities of Affection. — Starting from this assumption, we may consider affection in its relation to the various stimuli, enumerate its qualities and its physiological accompaniments, in much the same way as we have treated the cognitive processes. First, with reference to the qualities of feeling, it may be asserted that there are but two, *pleasantness* and *unpleasantness*. Many objections have been raised to this statement. In the first place, as has been seen, many people mean altogether different kinds of mental processes, intuitions and what not, from those that we have admitted into the class. These we may exclude by mere arbitrary definition. They certainly have an existence and a place in psychology, but fall rather under reasoning and other heads than under feeling.

They simply are not sufficiently like the processes we are discussing to make it possible to extend the term to include them. Wundt, using the term in somewhat our way, makes the suggestion that there are many different qualities of feeling, one for each sensation and intellectual process. To this the majority of psychologists stand in direct opposition. The differences that strike one are due rather to the qualities of the accompanying sensations than to the feeling qualities themselves. If one can abstract the sensational elements from a feeling, the purely affective remnant is always the same — pleasant or unpleasant.

Pleasantness and Unpleasantness the Only Qualities of Affection. — To recognize only pleasantness and unpleasantness as qualities of affection is opposed to many authorities, ancient and modern, but the distinctions they draw seem to be based on other than psychological grounds. Thus, the moralist of everyday life draws a distinction between higher pleasures and lower pleasures. One is the pleasure from the simple senses, the pleasures of eating, for example, particularly the pleasures from the satisfaction of the simpler instincts; while the higher pleasures are the pleasures of the imagination, æsthetic pleasures, the pleasures from moral acts. In general, they are the pleasures which society approves, while the lower pleasures are those which are either disapproved or regarded as morally indifferent. This distinction is recognized by every one. It is at the basis of one of Dr. Johnson's favorite distinctions between pleasure and satisfaction. Still it is generally believed not to correspond to any *real* difference in psychological quality, but rather to a distinction based upon ethical considerations. Sensuous pleasure is believed to be of the same quality as moral pleasure; the pleasure from a pleasant odor, of the same quality as that from a painting by an old master. The difference is to be found in the fact that one is approved by the connoisseur, carries with it a certificate of being beyond the ken of the multitude, and takes an added flavor from that fact, a flavor which may intensify the other quality but is of the same general class or type. Other suggested qualities of pleasant and unpleasant seem on analysis to reduce to similar extraneous considerations and to leave but two qualities, pleasantness and unpleasantness. In general, one must admit with Wundt that the total feeling varies with each stimulation and with each sensation or memory or other sort of mental state; however, the variation is not in the affection but in the sensational accompaniments. The pleasantness or unpleasantness is, if we are to believe the introspections of the large mass of psychologists, always identical; and the differences that Wundt insists upon are to be found in the cognitive accompaniments. The differences between sensuous, æsthetic, and moral pleasures or displeasures are in the occasions of the affections, in the cognitive component of the feelings rather than in the affective elements themselves.

Other Suggested Pairs of Feeling. — As emphasizing our conclusion that there are but the two qualities of affection, we may consider the view of Wundt that there are three pairs of qualities in feeling, not one pair. To pleasantness-unpleasantness he adds strain and relaxation, excitation and quiescence. Strain and relaxation are related to the feeling of effort and its lack in attention, — strain appears in expectation, relaxation in realization. Wundt insists that these qualities do not come from the contraction of the muscles and their relaxation, but are as truly affections without assignable sense organs as are pleasantness and unpleasantness. Excitation arises when one is disturbed through attempting a difficult task, is a component of anger and of certain exhilarating forms of joy. Quiescence or inhibition is an accompaniment of rest, perhaps of lassitude. They, too, are peculiar qualities of affection with no sense organs and no definite relations to the other forms of feeling. These extra pairs were supposed to be accompanied by special physical reactions, but later investigators seem to have pretty clear evidence that the experiments in support of them were inaccurate or wrongly interpreted. On the whole, direct observation seems not to bear out Wundt's contention that these forms of consciousness are feelings. There can be no doubt that the states exist, but they seem to be either directly due to special sensations such as the kinæsthetic impressions, in strain and relaxation, or to more complicated organic processes, in excitation and quiescence. These are probably closely related to the qualities of the emotional states to be discussed in the next chapter. In any case they are not affections in the same sense as are pleasantness and unpleasantness.

Intensity of Stimulus and Intensity of Affection. — The other attributes of affection call for but brief discussion. The intensity of each quality of affection varies from zero to a maximum that may end in the loss of consciousness. The relation to the intensity of stimulus has been expressed by Wundt in a curve that holds for stimuli of certain kinds, although there may be exceptions. A faint stimulus is usually indifferent. As the intensity increases, a pleasant affection begins and increases to a maximum with moderate excitations, and then drops to

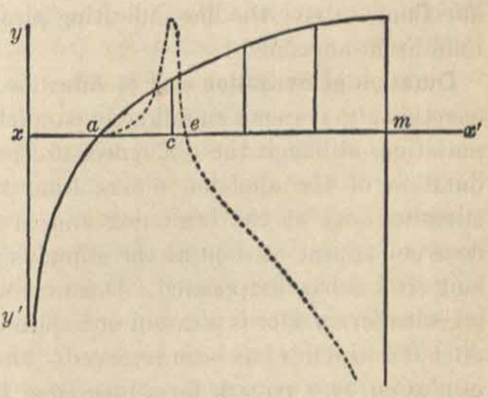

FIG. 79. — Schematic diagram of the relation of affection to sensation. The smooth curve shows the rise of sensation with intensity of stimulus, the dotted line the accompanying rise and fall of pleasantness and the increase of unpleasantness. (From Wundt.)

indifference, and finally becomes unpleasant as the excitation is increased still more. The point at which pleasantness disappears varies with the nature of the stimulus. Only very faint pains are pleasant, they become unpleasant at an intensity not much above the limen. Bitter substances in very weak solutions may be pleasant, as in chocolate or bitter almond; they are unpleasant in relatively weak solutions. Sweet on the other hand is indifferent when present in very small quantities, and becomes unpleasant if at all only in very strong solutions, as may be obtained by saccharine. With suitable allowances, practically all sense qualities will be found to correspond with the rule in some degree. It at least approximates a law. In the diagram, the line *a* indicates the increase in sensation by the logarithmic curve in accordance with Weber's law; *e*, the curve of increase in intensity of affection — above the line indicating pleasant, below the line unpleasant affection.

Duration of Sensation and of Affection. — The duration of affection also does not run directly parallel to the stimulus and sensation, although the differences are not so marked. The duration of the affection differs from the duration of the stimulus both at the beginning and at the end. Affection does not appear as soon as the stimulus and usually persists long after it has disappeared. One may spend minutes deciding whether an odor is pleasant or unpleasant and be sure only after the stimulus has been removed. One may be pleased or displeased by a remark for a long time after hearing it. On the other hand, affection may change its character while the stimulus persists. What at first is pleasant may become indifferent or even unpleasant while the stimulus persists unchanged. Duration has much the same relation to affection as intensity in this respect, and one might draw a similar curve. The tendency is always for the feeling to become unpleasant rather than pleasant as its duration increases. No general rule can be given even for the same stimulus as to how great the duration must be before the quality will change.

Affection and the Qualities of Sensation. — It would be highly desirable, were it possible, to give either a catalogue or some general law that should classify the objects or stimuli that give rise to pleasure or displeasure. We have already attempted this for the intensity and duration of stimuli. To list the qualities that are pleasant is much more difficult. Experimental æsthetics has made the attempt in certain fields, but the results are too voluminous to be presented in detail, and the general summaries are too few and too schematic to be very satisfactory.

Bodily Accompaniments of Feeling. — In discussing the effects of feeling in determining the action of an individual, we attempted to find an explanation of the effect in the slight movements that accompany the stimulus and the explicit movements. While we had no special success in our attempt to find an explanation of the effect by that method, we must examine them again to see if they afford any explanation of the consciousness of feeling, or give an indication to the onlooker of the sort and degree of the feeling. Common observation agrees that feeling can be read in the face. The face is said to light up or to lower, and the general bodily attitude changes in accordance with the feelings. In most cases the presence of pleasure or its opposite can be readily and clearly detected by observation. Many investigations have been undertaken and carried out to translate these simple observations into more accurate measurements. One of the first series of studies was of the changes in respiration and circulation. The first results seemed to indicate that there was a definite opposition in these processes corresponding to the opposition between pleasantness and unpleasantness. Thus Lehmann asserts that in pleasure respiration is slow and deep; while in unpleasantness, at least after an initial inhibition, it is quick and shallow. The pulse, similarly, is said to be slow and strong in pleasure, and quick and weak in unpleasantness; the blood vessels dilate in pleasure, contract in unpleasantness. Investigations over the last thirty years make it very clear that Lehmann was too optimistic in his interpretations. It seems certain that the changes in circulation and respiration vary with the strength of the stimulus and the attention given to it. All stimuli tend to quicken the respiration and make it shallow, to quicken the pulse and make it feeble, and to constrict the blood vessels. It is altogether probable that Lehmann's results with pleasure were due to the fact that pleasant stimuli are usually faint, and so if there has been strong stimulation just before, the vital processes tend to return to normal, and thus seem to show changes that are the reverse of the effects of the stimulation. Wundt and his students have attempted to demonstrate peculiar physiological changes of the same sort in connection with his suggested pairs of strain and relaxation, exaltation and depression; but study of their curves indicates that they have been misled by similar phenomena of recovery, and by rhythmic changes that have no relation to the changes in the feeling that they are studying.

The Galvano-Psychic Reaction. — Much studied also has been the change in the electrical resistance of the skin that occurs during an affective state. A man has applied to his skin electrodes of a character to avoid themselves exciting electric currents by chemical reaction. A faint current is then introduced and measured by a galvanometer. It is found that if a pleasant or unpleasant stimulus is given to the man, the resistance of the skin is markedly decreased. It is also found that a current may be induced spontaneously from the skin. It is still not definitely settled to what these phenomena are due. Most probably the change in resistance comes from secretions of the sweat glands which moisten the skin and so make it a better conductor. If one suffers pain perspiration increases, as can be readily noticed, and the same holds for great pleasure. Possibly other factors are involved in addition to the secretion of the sweat glands, since some changes are noticed when the electrodes are inserted through the skin into the muscle. This would reduce the skin contact to a minimum and so the effect of the increased perspiration. No satisfactory suggestion of causes other than glandular secretion has been offered.

Glandular Secretions in Feeling. — Other glands are also affected in their secretions by pleasure. Pawlow has studied the secretion of saliva, which is increased by pleasure of all sorts, as well as by foods, and which is inhibited by pain or strong displeasure of any kind. The mouth is dry in any prolonged intense unpleasantness. More frequently observed is the secretion of tears. All are familiar with the tears of weeping from unpleasantness of any kind in high degree. Less frequently noticed is the increased lacrymal secretion in pleasure. Occasionally a susceptible individual weeps from joy. All show a brightening of the eye in pleasure, which is due to a slight moistening of the conjunctiva and cornea by tears.

Contraction of Voluntary Muscles. — Intense feelings both pleasant and unpleasant are accompanied by marked motor contractions in most of the striped muscles of the body. One leaps for joy on occasion. More frequently intense joy induces a general contraction of bodily muscles. More obvious are the contortions of the bodily muscles in intense pain or unpleasantness. As the dentist drills at a living tooth, the hands grip the arms of the chair, muscles of the arms and legs are contracted to brace the body against any object available. These general contractions have been shown by Dumas and Piéron to be effective in reducing pain. Measurements made of the least pressure that would cause pain, first with the muscles relaxed and then while pressing upon a dynamometer, showed that the limen was much higher. Stronger pressure was required to produce pain when the muscles were contracted than when they were relaxed. Whatever the mechanism involved, the muscular contractions which arise spontaneously do have an actual tendency to reduce pain.

The Facial Expressions of Feeling. — Most obvious of the motor accompaniments of affection are the movements of the face. In general these are opposed for pleasantness and unpleasantness. The mouth and the eye-brows have an upward curve in pleasure and a downward curve in displeasure. This opposition is much more pronounced in mild affections than in intense ones. Pictures Dumas obtained of a Chinaman subjected to torture as a legal punishment indicate that in extreme pain the face may show an almost ecstatic expression of pleasure. Even facial expression is not unambiguous. The muscles of the mouth are more significant than those of the upper part of the face in determining the interpretation that shall be put upon the expression, and probably are also the first to show the state of feeling. Slightly better evidence may be given for an opposition in expression in the bodily posture. Grief seems to be marked by a drawing together of all the members, while pleasure leads to an actual physical expansion, — head erect, even thrown back as in laughter, the arms extended and the trunk held straight. These general bodily movements have been much less carefully studied than the others, and the opposition of the different kinds of feelings shown in superficial observations may disappear upon fuller investigation.

Physiological Explanation of Expression. — Some light may be thrown upon the relation of the expressions to the feeling from a study of the physiological connections that make them possible. The expressive reactions seem to involve processes very widespread in the nervous system. They are only slightly dependent upon the cortex, for weeping and changes in the size of the pupil can be seen in babes born without a cortex. Animal experiments show that the thalamus is likely to be a reflex center through which relatively widespread irradiations of the expressive movements may be effected, although the medulla is sufficient for the change in the size of the pupil and some other responses. The last step in the transmission to the unstriped muscles in the heart, in the iris for the pupil, and to the glands of secretion is through the autonomic nervous system. It has been asserted that the sympathetic system is the organ for unpleasantness, since through it are evoked the secretion of tears, dilation of the pupil, inhibition of alimentary canal peristalsis; while the parasympathetic system, the cervical and sacral branches of the autonomic nervous system, supply the organs of pleasure. The parasympathetic system transmits the impulses to the salivary glands, induces secretions of the digestive fluids, and activities of the sex organs. The parallel between the two sorts of feeling and the activities of the two parts of the autonomic system is only general. The most marked defect in the assumption of a causal relation between feeling and the autonomic system is that pleasant excitement excites the sympathetic system in much the same way as does pain or unpleasantness.

The question as to how any of these nervous reactions might be responsible for the conscious qualities of pleasantness and unpleasantness is just as unsolved, when we have pointed out what the physiological processes are that accompany them, as it was before. We have seen that the accompaniments are not altogether distinct for the two important opposed qualities of feelings. If they were, the problem would not be solved for most of the changes that take place are in organs that give rise to no sensations. If the connections were consistent and the movements were conscious, we might say that certain organs when they responded served as danger signals; that, when a stimulus was dangerous there was an automatic contraction of the walls of the blood vessels; that this was at the same time registered in consciousness and produced a withdrawal movement through the voluntary muscles which removed the animal from danger. A theory of this kind fails at three points to harmonize with the facts. There is no known way by which dangerous stimuli could make a different impression on any of these organs from innocuous impressions; in the second place the responses are for the most part not conscious, and in the third place there is no known connection between these contractions and the motor centers for the muscles that control the movements of withdrawal. The presence of expressive movements explains consciousness of feelings no more than they explain why the animal or child makes the movements of withdrawal or approach that are connected with them. So far as we can see now, these incidental bodily changes are merely accompaniments of the conscious feelings; they do not explain how the qualities originate. The problem must be discussed in a slightly different form in connection with emotions which are accompanied by more pronounced movements.

Theories of Feeling

Many theories of feeling have developed in the history of psychology. While no one of these can be said to be final, they give together an idea of the different emphasis that has been put upon the facts at different times. We have seen that one cannot point to any special part of the nervous system as especially connected with feeling. Each of the theories is relatively general in its terms.

Physiological Theories. — A very widely known theory regards pleasure and displeasure as the accompaniment and indication of benefit and injury to the organism. This takes different forms, either as an expression of an immediate change in the organism in general, of the nervous system as a whole, or of some particular part of the nervous system. It may be an indication of what has been good or bad for the individual or race in the past and is likely to prove so in the future. For these theories, pleasure means that there is in the individual at the moment a process of upbuilding, of anabolism; that this anabolism is induced in the nervous system as a whole or in the frontal lobe, — for Wundt the great coördinating center for all nervous and mental activity. The evidence for each of these theories is indirect and may be found in the general law that the beneficial is on the whole pleasant, that the injurious is on the whole unpleasant. Correspondingly, when one is physically in good health, well rested and nourished, many activities and even excitations are pleasant which become unpleasant when the physical tone is lower. These facts have been interpreted to mean that action of a well-nourished nervous system or part of the nervous system means pleasure, and that action of a badly nourished system means displeasure. Taken literally, the identification of pleasure with anabolism, and displeasure with katabolism, would make all action and stimulation unpleasant, since all action involves use of nerve substance. The anabolism-katabolism formula has been modified by permitting katabolism within moderate limits, the limits of ready recuperation, to give pleasure. This limit would be difficult to determine empirically, however.

Evolutionary Theory. — Another change in the statement of the theory permits the formula to mean a general benefit or injury to the race in the evolutionary sense. This enables one to account for many of the seeming discrepancies between benefit and pleasure. Thus, it seems at first not true, even in general, that the pleasant in food or drink is also beneficial. Aside from exceptions, however, we do use feeling as a guide to foods. We eat what we like, or at least we do not eat what we do not like. The exceptions apply to excesses or to subsstances of rare occurrence in the environment in which the race evolved. The race as a whole is more likely to survive if it makes use of pleasant but injurious foods, such as sweet poisons, than if it ate no sweets. The exceptions must be learned by individual experience. It is much better to eat than not to eat, in spite of the fact that overeating is harmful. When to stop can be learned from the unpleasant symptoms that indicate injury. Pleasantness and unpleasantness serve as a general guide to conduct, and may be said, metaphorically, to be the expression in the individual of the experience of the race as to what is good or bad. This expression is open to many exceptions, is not a final law, but must be modified by the experience of the individual and the accumulated knowledge of the race. It should be added that the manner in which the experience is recorded and transmitted in the individual, and how and why it acts, are not at all known. The theory is nothing more than a formulation of the general group of facts that, in the long run, what pleases, benefits; what displeases, harms.

Furtherance-Hindrance Theories. — Another group of theories accounts for the more active pleasures largely overlooked in the theories just mentioned. This group couples easy running or unopposed action with pleasure, difficult or opposed action with displeasure. In one form the theory makes real physical movements the basis, in other groups it is taken in a more metaphorical sense. Thus, the first theory states that a smooth, graceful curve is pleasant because the eye will follow it without effort, with a single sweep; while a series of short lines with many changes in direction is ugly because of the difficulty of the eyes in following them.

Einfühlung Theory. — A slight extension of the furtherance-hindrance theory is seen in Lipps' theory of empathy (*Einfühlung*). This extends the furtherance-hindrance notion from one's own body to all external objects. Lipps believes that one tends to identify or read the self into all external objects. As one looks at a vertical line one feels an upreaching as if one were the line. The sight of a slender column supporting a heavy building evokes in the observer the strains that he would have were he himself holding up the too heavy weight. Probably these arise from kinæsthetic sensations reflexly aroused. Whatever the origin, Lipps assumes that all æsthetic enjoyment comes from a harmony of the inner movements excited by the objects seen. Where there is harmony between the internal reactions and the mood, the observer is pleased; where there is conflict, the observer is displeased. The object that excites conflict within is ugly; the one that is observed with harmonious responses is beautiful.

Finally, we have Stout's theory that one may have opposition in the accomplishment of an intellectual purpose, in reaching some conclusion in thought; or, on the contrary, one's mental operations may run smoothly or be helped, and so be pleasant. In each of these cases furtherance or easy action means pleasure, hindrance or interrupted action, displeasure. As before, one may accept the general statement, particularly in the metaphorical form, although the more specific applications offer much room for doubt and may be disputed as to facts.

Feelings Dependent upon Earlier Experiences. — The third form of theory attempts to explain how feeling can be dependent upon such a wide range of experiences, rather than why one is pleased or displeased. The first form of this theory is Wundt's statement that feeling is the obverse of, or at least one phase of, apperception. For Wundt, apperception is practically synonymous with the active life, covers much of what is treated under attention, perception, and will. It is the effect of the entire earlier experience of the individual in the control of his present action in attending, in interpreting the material offered to perception, in thought, and in practical conduct. This definition makes feeling an expression of the interaction between the coördinated earlier experience of the individual and the present experience. On the nervous side, Wundt gives apperception a seat in the frontal lobe, probably in the front portion of the frontal lobe, and so combines his psychological theory with the physiological in the formula mentioned above, — that pleasure corresponds to the action of a well nourished, displeasure to the action of a badly nourished, frontal lobe. This means, or may be made to mean, that whether any process is pleasant or unpleasant depends upon the entire accumulated experience of the individual and in the way that experience is brought to bear upon the process in question, a statement that is undoubtedly true, although somewhat vague. If we replace apperception by attention, and consider the nervous factors that are found to determine the control of attention, we should have approximately the same formula in our own terms.

Summary. — Feeling is important for behavior as an innately determined tendency to approach a particular object or stimulus or to withdraw from it. As a determinant of responses it decides whether a movement is to be repeated or avoided. Not only does it determine what response is to be made to a stimulus but it also determines whether a repetition is to be more or less effective in establishing a habit. In this sense feeling is the great determiner of all types of responses. We shall see that it has also been alleged to have the same determining function in relation to the memory processes. On the side of consciousness, feeling is primitive and unanalyzable. It gives a glow or a gloom to experience that we all know, but cannot describe. It is a reaction of the organism as a whole to a stimulus or a small group of stimuli. The fundamental determinants of the reaction are inherited. Approximately, feeling is an indication of safety or danger to the organism in any situation. While the inherited elements predominate in determining whether the response shall be positive or negative, the experience of the individual also changes it. Things disagreeable at first may become indifferent or even pleasant.

The widespread changes in vital processes that accompany pleasure are interesting as showing the degree to which the organism as a whole is affected but they cannot throw light upon why we feel as we do. They are not the specific cause of the quality, nor are they the immediate occasion for the responses that give the feeling its practical importance to the individual. The function of feeling is apparently to give direction to the entire life of man or animal. How it came, what the mechanism is by which it acts, or whence its omniscience is still an open question. The external functions can be traced sufficiently accurately, but neither its neurological mechanism nor its remoter conditions can be made out.

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CHAPTER IX

EMOTION

AMONG the most interesting of mental processes theoretically and certainly the most outstanding in the life of the individual are the emotions. Emotions are closely similar to feelings. They differ from them only in that they involve a more widespread motor discharge on the one hand, and that they are more likely to be determined by appreciation of a situation than by a simple response to a stimulus. On the motor side they are innately determined responses to a situation, as are instincts. Emotions differ from instincts only that they involve primarily responses which have no goal outside of the body. The movements in emotion may give an idea of the attitude of an individual towards an object; they themselves accomplish nothing in the world outside the individual. Anger is different from unpleasantness only because it is usually directed towards another individual in a specific relation, and because there is much more definite awareness of internal reactions. Anger is different from the innate reaction of withdrawal or rejection because of a series of contractions of muscles within the body which last long after the external response is complete. If one should by mistake take quinine into the mouth instead of the expected powdered sugar, he would spit it out with no great emotion. If as he tasted it he saw a companion smiling in a gloating way and be convinced that the companion had substituted quinine for sugar in the bowl, he would show and feel the bodily reverberations characteristic of anger.

Bodily Excitations in Emotion. — Psychology is in modern times most interested in the bodily processes which express and constitute the way the individual is aware of the emotions. Many of the bodily changes in feeling were enumerated in the preceding chapter. In emotion movements are very much more pronounced and more obviously the basis of awareness. Many social relations are determined by the interpretation put upon the facial and general bodily movements in the emotions, and the emotions as the awareness of expressive movements are the true core of the individual's mental life. The motor accompaniments of an emotion are different from the effective external pattern reactions that are usually called instincts, in that they involve the autonomic nervous system and the unstriped muscles more than they do the central nervous system and the voluntary muscles. They are also relatively little influenced by learning. One can learn to inhibit the expressions of the face, but one cannot control, or can only in minor degree control, the large mass of muscular contractions and glandular secretions released by the autonomic nervous system. Only in limited degree can one feign an emotion that one does not feel.

The Autonomic Nervous System in Emotion. — If the central nervous system is dominant in learned and in overt innate responses, the autonomic nervous system is dominant in emotional responses. The autonomic nervous system, it will be remembered from Chapter III, is a series of ganglia, outside of but near the central nervous system, which send mainly motor fibers to muscles which control the size of the pupil, the muscles in the walls of the blood vessels, the erection of hairs, the movements of the visceral organs in general, and the secretions of all of the glands. The autonomic ganglia are connected by axones with the central nervous system and receive motor impulses from them over the white rami. They have few if any sensory fibers of their own. Impulses are

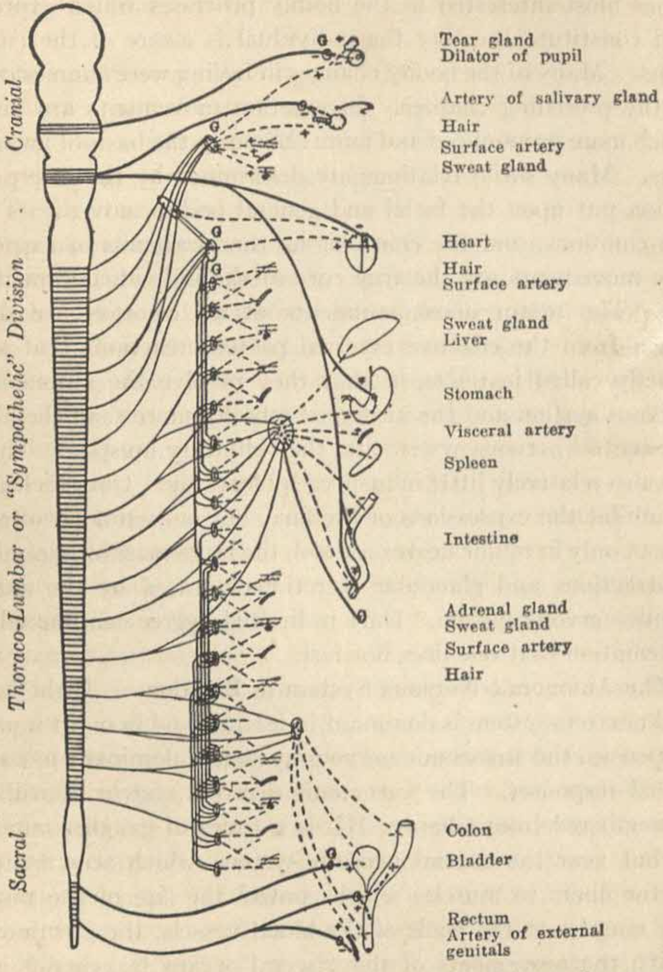

FIG. 80. — The autonomic nervous system. At the right are the names of the organs supplied from each level. At the left are the names of the three great divisions. (From Cannon, "Bodily Changes in Pain, Hunger, Fear, and Rage," by permission of D. Appleton and Company, publishers.)

transmitted more slowly in the autonomic system than they are in the central nervous system, and the impulses spread much more diffusely.

In practice it is customary to oppose the *cranial* and *sacral* branches of the autonomic nervous system to the *sympathetic* branches which are given off from the upper and middle portions of the cord. The cranial and the sacral are active in pleasant states and in neutral emotional conditions. The sympathetic are aroused in all states of excitement or emergency, and are especially likely to be active in unpleasant emotions. The cranial nerve contracts the pupil, evokes peristalsis in the alimentary canal, causes secretions of the salivary glands and digestive fluids. The sacral causes reactions in the sex glands and in the lower intestine. The sympathetic branch inhibits all of these responses and causes erection of the hairs in the animals and goose flesh in man (probably the vestigial remnant of the erection of the hairs in animals), changes in the heart rate, size of blood vessels, and evokes secretions of adrenalin. This interaction of the sympathetic with the cranial and sacral, together known as the parasympathetic, is characteristic of emotion. To these are added contractions of a number of the striped muscles.

Qualities of Emotion. — The importance of bodily processes in coloring emotion has been recognized from the earliest times. The Greek philosophers had much to say of the bodily processes in emotion and were very full in their descriptions of the accompanying physical states. Thus, Plato assigned courage, ambition, and the nobler emotions, to the heart; while lust and the baser passions had their seat below the diaphragm. In common observation one may find the explanation of these references to the body in the sensations derived from the general region of the body in which the movements are felt. The changes in rate of breathing, in the circulation, contractions of the muscles of the chest and abdomen, all are noted by the chance observer and are prominent in the novelist's descriptions of mental states. While the modern author no longer ascribes the emotions to the internal organs in the same sense as did the ancients, he still looks to the organic sensations for the coloring of the emotions; in fact, for a quarter of a century, psychologists have been engaged in a controversy as to whether these organic changes do or do not explain both the origin and the content of emotion.

The James-Lange Theory. — This controversy began with and has revolved about a theory propounded simultaneously by Lange and James. The theory, stated briefly, is that the movements of the body, when felt, are the emotion; and that the mental factors are altogether subordinate. James states it in the apparent paradox that you are sad because you weep, rather than weep because you are sad. He enumerates a number of cases in which the emotion comes only after the movements have been felt. One may face a situation with no great appreciation of its danger, even with knowledge that it is not dangerous, and suddenly become aware of a trembling, together with a sinking feeling in the abdomen; with this movement the emotion of fear is fully established. One may look over a cliff with perfect confidence of safety, and then suddenly feel a dizziness and trembling that destroys one's self-assurance and even compels one to draw back involuntarily. In these cases action and thought seem to be at variance, and action takes precedence over thought. The theory in general must be accepted as at least a rough statement of certain facts, and this makes it necessary to examine carefully the opposing arguments.

The External Signs of Emotion. — Modern investigation with instruments and methods that were not available when James wrote has turned to a more careful determination of the reactions in emotion and to the question whether they really give the consciousness of emotion. Cannon has taken the lead both in experimentation and in discussion. The investigations bring out in detail the activities of the autonomic nervous system. In the pleasant emotions the increased flow of saliva and of the gastric fluids is prominent. Pawlow's experiments on the dog mentioned in the previous chapter emphasize them. That these secretions are inhibited in fear or anger is evident from the dry mouth during those emotions. The Indian rice test for guilt illustrates it vividly. If a man is suspected of a crime, he is required to take rice into his mouth. If, after a period, it comes out dry, the man is adjudged guilty, if moist he is innocent. Flow of the gastric juices and the peristaltic movements of the stomach and intestines are also inhibited in strong and especially in unpleasant emotions.

The Adrenal Glands in Emotion. — Possibly Cannon's most important contribution to our knowledge of particular bodily reactions in emotion has come from his study of the responses of the adrenal glands. It will be recalled that these are ductless glands near the kidneys. The medulla or inner portion of the glands secretes a fluid, known as adrenalin, directly into the blood. The glands are stimulated to secretion by a branch of the sympathetic nerve, the splanchnic, which is excited in all violent emotions, by pain, anger, fear, and by general excitement. The effects of this secretion are widespread. Briefly enumerated, it serves first to contract the small blood vessels and to increase the ease with which the blood will clot. This action may be illustrated by the use made of it by the physicians in applying *adrenalin*, the substance obtained from the adrenal glands of animals, to stop superficial bleeding. A second action of the glands is to increase the amount of glucose, or so-called blood sugar, in the circulation. This seems to be due to the action of the adrenal secretion upon the liver, causing it to release its stores of glycogen which is introduced into the blood and is carried to the parts of the body that may need them. A secondary consequence of these actions is that the effects of fatigue are checked for a time, and the muscles respond with renewed strength. This increase in effectiveness is due in part to the fact that the constriction of the blood vessels increases the blood pressure, and so more thoroughly and quickly washes out the poisonous products of earlier action; and in part to the fact that the glycogen furnishes a quickly assimilated food to the muscle. It could be demonstrated that stimulation of the adrenal glands produced each of these effects, the blood vessels were contracted, the blood pressure increased in consequence, the composition of the blood was changed so that it coagulated more easily, the liver was stimulated to secrete its sugar and, as a result, fatigued muscles were temporarily increased in strength.

These same effects were all produced by pain or strong emotion, provided the adrenal glands were present and connected with the sympathetic system. The increase of blood pressure in emotion is well known, and experiments showed that the blood would coagulate more quickly after strong emotion. The increase in the sugar in the blood was demonstrated in cats subjected to pain, or frightened by dogs when no injury could be done them. The same effect is exerted in man. It was found that of twenty-five players on a Harvard football squad twelve had increased secretion of glycogen, as shown by sugar in the urine, after the contest was over. That this condition was in part due to emotion was shown by the fact that five of the twelve were substitutes who took no part in the game and that the only excited spectator examined also showed the same reaction. Students examined before and after a difficult and important examination showed presence of glycogen after, but not before, the test.

Looking at the phenomenon as a whole, one may readily see the utility of these reactions in emotions. The strong emotions, particularly the unpleasant emotions, are in animals, and were in primitive man, very likely to be followed by a fight or other violent effort. The animal subject to emotion must usually either fight or run. The bodily changes are a preparation for this effort. The contraction of the blood vessels in the abdomen forces blood into the peripheral vessels and the respiratory tracts, preparing them for greater effort at the expense of the digestive tract, which temporarily ceases to function. The increased glycogen and more rapid circulation under excitement supplies nourishment to the muscles and removes the products of fatigue, thus making them capable of greater activity. The constriction of the arteries and quicker clotting of the blood serve to diminish the hemorrhage in case wounds are received in the conflict. All together, emotion increases the energy of the individual and lessens the liability to injury. It is said in this connection that an artificially induced anger has been used by some individuals to spur them to greater effort.

Cannon Rejects the James Theory. — In spite of having contributed so much to our knowledge of the bodily changes which occur during the emotions, Cannon cannot accept the theory that our experience of emotion is due to these bodily changes. He finds a number of reasons for this skepticism. First he states that there are a large number of physiological reactions common to emotions of all types. Secretion of tears, inhibition of gastric secretions and secretion of saliva are characteristic of all strong emotions, whether they are classed as pleasant or unpleasant. The same secretion of adrenalin, with the widespread effects, also characterizes all strong emotions. It is found in the dog barking at the cat in the cage, as well as in the cat. He argues that this precludes assigning the qualities of the emotions to the bodily changes.

Bodily Changes Come Too Slowly. — A second objection is that the bodily changes, most of which are due to the excitation of the autonomic system, are too slow to be regarded as the cause of the emotion. Measurements show that emotional states arise in as little as half a second after the situation is presented, while from eight tenths of a second to six seconds is required for the secretion of adrenalin or for the inhibition of the peristaltic movements. We feel the emotion before the bodily changes begin.

Internal Organs Are Insensitive. — Cannon's third objection to the theory is that most of the organs that respond in emotion do not give rise to sensations. As was said in the chapter on sensation, most of the internal organs when stimulated either do not give rise to sensations or to very slight ones. Changes in the blood vessels, the contractions of peristalsis and most other emotional responses are not appreciated or are appreciated only slightly.

Emotions Appreciated without Bodily Changes. — Judged by external responses cats have emotions when the sympathetic system is lacking. Cannon found it possible to remove the sympathetic ganglia from a cat and keep it alive. After the operation there was no erection of the hair, there was no indication of adrenalin secretion, but the facial expression and bodily attitude indicated that the emotions were still retained. Sherrington nearly twenty years earlier drew the same conclusion from experiments of cutting the cord in young pups. The upper part of the cord was sectioned which destroyed the connections between all of the viscera and the brain. After the operation the pups showed the same emotional response as before, had the same emotions as inferred from the reactions of the muscles of the head. It was objected that associations may have been formed between the stimulus to the emotion and the expression of the muscles of the head by the intermediation of the bodily responses, and that these connections remained after the sensations from bodily responses had been cut off. This objection was obviated by repeating the experiments on puppies only three weeks old who had had no chance to form this indirect association. The results in this case were the same as before. Sherrington is convinced that the emotion is the result of cerebral rather than of somatic reactions.

Of more direct bearing upon the problem are reports of patients who have suffered injuries to the cord that break the connections between the brain and the parts of the body involved in emotion. Cannon cites a case reported by Dr. Dana of a woman whose neck was broken and who lived for nearly a year afterwards. The woman felt all emotions as usual in full strength and with unchanged qualities, although all sensory nerves from the viscera and from the body below the neck were cut off from the brain. There could be no sensations from the viscera of any kind. Other cases are cited for whom injuries to nerves produce automatic weeping and other marked emotional movements with no corresponding emotion. One patient warned her companions that they should pay no attention to these expressions because they did not at all correspond to what she felt. Dr. Wilson, a British neurologist quoted by Cannon, infers from these cases " The conclusion is unmistakable that the bodily reverberation, as James calls it, is not *per se* the emotion."

Adrenalin Injected Does Not Cause Emotion. — Less definitely demonstrable is Cannon's fifth contention that adrenalin taken or injected does not produce an emotion, although the effect upon the physiological functions is the same as is produced by secretions of the individual's own glands. He quotes his patients as saying that they felt on edge as if they might have an emotion aroused readily, but did not really experience the emotion. Some observers, however, contend that adrenalin injected does produce true emotions.

The Thalamus the Seat of Emotions. — On account of these five facts, Cannon concludes that the emotions are not merely the sum of sensations excited by the movements of visceral and other organs. Instead, in the second edition of his *Bodily Changes in Pain, Hunger, Fear, and Rage* he states his conviction that the awareness of the emotion is due to changes in the thalamus. As was said in Chapter II, all motor processes from the cortex to the lower body pass through the thalamus, as do all sensory processes from the body to the cortex. Cannon's belief is that as the widespread impulses to the autonomic system are transmitted through the thalamus, they excite nervous processes which return to the cortex and so give rise to the mental processes which we call emotion. After the emotion has been aroused in this way, the motor impulses continue on their way to the autonomic nervous system and to the lower motor organs of expression and produce the bodily effects. The efferent discharges incidental to the experience are responsible for the awareness of the emotion. They do not, according to Cannon, need to produce actual movements, and have sensations return from the moving member to the cortex, before we know we are angry. A back thrust from the thalamus to the cortex gives that awareness.

Evidence from Pathology for the Thalamic Basis of Emotions. — Cannon's positive evidence for the thalamus as essential to emotion is derived from individuals in whom the thalamus is injured. Bechterew and Head both report cases relevant to the problem. Motor control of the facial muscles may be either automatic or voluntary. The automatic control is through the thalamus. If that be injured the patient will no longer smile in immediate response to a situation although he may voluntarily frame the mouth in a smiling position. On the other hand the path for voluntary control may be destroyed, while the automatic paths may be open. More interesting are unilateral lesions of the thalamus which result in paralyzing the expression on one side of the face and leaving it normal on the other. The patient smiles or scowls with one side of the face only, the other is impassive.

Direct evidence that the thalamus is essential to the consciousness of emotion is provided by these cases. They report in certain instances that they do not appreciate emotion. More frequently the emotional response is exaggerated. One patient asserted that a simple Salvation Army song which before the disease would arouse no interest, afterwards caused an emotion of joy so strong as to be almost painful. All this harmonizes with Head's general theory that the thalamus is the seat of the relatively vague processes and responses, while the cortex cares for the definite specific acts. While the case cannot be regarded as definitely closed, Cannon seems to have adduced very strong evidence against the James theory. He of course leaves unaffected the whole mechanism of emotional expression. His only modification is as to the point from which the back stroke to the cortex begins. He puts this in the thalamus rather than scattered diffusely through the body, as James pictures it.

Cannon and Qualities of Emotion. — A question might arise whether any part of the emotional quality would be connected with the bodily discharges on the Cannon theory, or what the function of these discharges might be. On his theory, the discharges would be mere incidents to the emotion as the bodily changes seem to be in the milder state of feeling. At the most one might argue that the organs towards which the different emotions were directed might vary, and that these paths in the thalamus might determine what the quality was to be. It seems implied in the theory that different regions in the thalamus are connected with different emotional qualities. At least the doctrine of specific energies, if it is to be applied to the thalamus, would make the assumption plausible or possible. These different areas would be excited by discharges towards different organs. Again, Cannon's objection that the bodily processes are too slow to be part of the emotion, would not hold against the cases in which the classification of the entire response is decided after the expression is completed. It is then that the classification is most frequently made. After an unusually strong emotional experience, one feels one's self weak and trembling, possibly perspiring or with deep breath. Only then may one appreciate how excited one may have been. This is not part of the true emotional consciousness, but is an intellectual evaluation of the state. As accompaniment, as determining the portion of the thalamus passed through, and as *ex post facto* elements in the appreciation of the emotion, the efferent motor discharges would still be important.

The Physiological Function of Emotion. — So far as emotions are physiological expressions we can say quite definitely that emotions are widespread responses of the unstriped and striped muscles of the body. More important psychologically is the problem as to what function they have, and under what circumstances they arise. The function may be treated as physiological, as psychological, and as social. The physiological function has been traced in the case of adrenalin secretion to a general increase of capacity to give and to take in a fight. Adrenalin increases capacity of the muscles to respond in any emergency by calling upon reserves of energy. It safeguards the body in case of hemorrhage. It stops the ordinary vital processes and throws the entire strength of the body into the external act during the period of the emergency. In fear, on the other hand, there is a paralysis in addition to, or in spite of, the general increase of energy which prevents the individual from contending with overpowering circumstances. These functions are mere statements that these physiological changes occur in the body when certain stimuli or certain circumstances present themselves and are appreciated. Emotion as such does not exist as a physiological process apart from this mass of responses. It is a series of responses within the body and largely independent of the overt purposive acts which still furthers the more obvious acts.

The Psychological Function of Emotion. — If from the behavioristic side, emotion is incidental to the attainment of the end, from the side of experience, emotion seems to be an end in itself. To experience a pleasant emotion, the ordinary man and especially the ordinary woman will make great sacrifices. Even to enjoy them vicariously as described for another is an important object of many hours of the daily life. Most novels and plays have their appeal from the fact that they present the emotional life of their heroes in great detail. The reader or observer shares in the emotions by living himself into these experiences empathetically. He feels the emotions as he reads. The day dreams and the practical plans of every man revolve about experiencing pleasant and avoiding unpleasant emotions in the future. These constitute the most important directing influences upon action in every phase of life. They are the real motives and drives. Not the actual attainment of a great end, but the emotional satisfaction in overcoming an opponent or of reaching a recognized position, is the real aim of most life. Picturing the success gives the emotion in advance in some degree, and this keeps the end in view until it is attained. In this way emotion controls most behavior.

The Social Functions of Emotion. — Most obvious of the functions of emotion is the control of social activities. From the earliest weeks the child comes to appreciate the probable conduct of adults from emotional expression, and adapts itself to these expressions. It smiles in response to a smile, and draws back in response to a frown. In adult life one appreciates what the conduct of a companion is to be from the facial expression and from other signs of emotion. One proposes a plan to the man who smiles, one withdraws from the man who scowls. One sees from an angry countenance that a remark has been misunderstood and hastens to correct the impression. In every field of business and social intercourse one makes use of the interpretation of emotional expression to adapt acts and remarks to the emotional attitude of the man with whom one is dealing. The emotional expression gives a better idea than words of what the real intention of a man may be and what attitude should be taken towards what he says or what he does. There can be no questioning the social importance of emotional expression.

Laughter. — A study of some prominent particular emotions may be made to illustrate different points. One of the most frequent and obtrusive of the emotional expressions is laughter. It may be considered with reference to its bodily expressions, its cause and its function. Psychology has little to add to the knowledge of laughter that is not available to the layman. Laughter is the culmination of a series of expressions of pleasure. The series begins with a smile, a drawing back and up of the corners of the mouth, a wrinkling of the skin at the side of the eyes, and a lighting up of the eyes, probably due to the slight secretion of tears. As the emotion increases in strength the mouth is more opened, the head is thrown back, the muscles of chest and diaphragm begin to contract, air is forced through the larynx and sound is added to facial expression. The contractions may increase to include most of the muscles of the trunk and limbs. Any omissions in the description may be checked by your own observations.

The Causes of Laughter. — While every one knows under what circumstances a man is likely to laugh, philosophers from Aristotle on have endeavored without great success to find a formula that will cover all cases. Aristotle asserted that laughter is caused by the observation of the misfortune of another. Hobbes modified this formula by asserting that the misfortune of another causes laughter because it shows our own superiority. It must be said that mild mishaps rather than serious misfortunes are the occasion for laughter. To see a dignified figure slip on a banana peel is amusing, but a broken bone causes sorrow. The more dignified the individual the more likely is the accident to arouse a laugh. Sudden changes are also more likely to evoke laughter than gradual ones. The suddenness of the turn seems to be the only occasion for mirth on hearing a pun. The more sudden the mishap and the greater the contrast between the earlier and the later state, the greater the laughter. In addition to these ironic causes of laughter there are a number that are much more benevolent. The babe smiles from mere bodily well being, and the child laughs from mere exuberance of spirits as he runs in a game. These are more in harmony with the common notion of the causes of laughter than the theorist's views.

The Function of Laughter. — Laughter has the same social functions as the other emotions. It induces a feeling of fellowship in a group and encourages advances and coöperation. Bergson has pointed out that laughter also has a specific place as a means of social discipline. When a group resents the approach of a stranger or objects to the remarks or the acts of one of its members, a general laugh is the surest way of disposing of him. This may come as the climax to a remark of another member of the group holding him up to ridicule, it may result from the reaction of the group to the act or remark itself. In any case only the most hardened individual can receive the laugh of a group directed against himself without unpleasant emotions. It is probably the most effective means of social discipline. Not all laughter is of the repressive type. Other occasions bring out expressions of spontaneous mirth as a signal of approval. The tone of the laugh and other gestures leave little doubt as to whether the laugh is of approval or of ridicule. The differences in tonal quality are slight, but the difference in emotional response is very great.

Types of Emotion. — Not many of the emotional states, possibly no other, can be so readily described in its bodily processes, its occasion, and in its functions as laughter. Few of the modern men have attempted an exhaustive classification of the emotions. They avoid it here as for instincts. All would agree that love, hate, anger, and fear are important representatives of the group. Few could agree on the detailed criteria that mark off one from the other. As has been said, the reactions of the autonomic nervous system show common elements for all emotions. Even the expressions of the face are ambiguous. Recent experiments frequently repeated show that there is great difference of opinion as to what emotion is indicated in any particular instance. If photographs of persons who have posed artificially for different emotions or who have been snapped in natural expressions are shown to a group of intelligent people, the judgment as to what emotion is portrayed will vary very greatly. What one man calls anger, another may call fear, and minor variations in emotion as between anxiety and curiosity give not more than 50 per cent agreement.

Love (Sexual). — No emotion, probably no other topic, has been so much discussed in popular literature as love. It is asserted in fiction and in some serious treatises that a life mate should be chosen for love alone. Many recent novelists and some philosophers assert that great love justifies any change in the matrimonial bonds, with no reference to social or parental responsibilities. All are very vague as to the criteria of true love. It is universally agreed that it is to be distinguished from lust. If we assume that lust is an expression of the bodily reverberations from the excitation of the sacral autonomic nerve, it would largely eliminate the som-

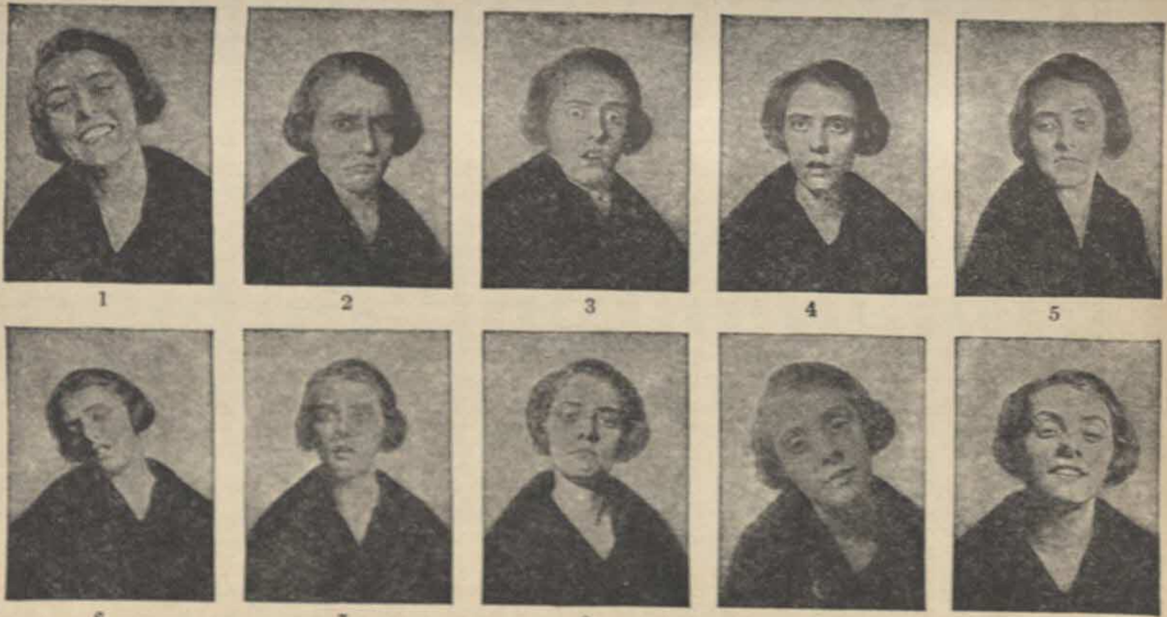

Fig. 81. — Reproductions of ten different emotional expressions. Name the emotion represented. Compare with the names assigned by others. For key see page 307. (From G. S. Gates, after Ruckmick.)

æsthesis from the criteria of the emotion. Novelists frequently mention general bodily glow, feelings of lightness in the chest, increased heart beat and other symptoms, but a statistical grouping of all the organic feelings mentioned would show many contradictions and would not furnish a reliable basis for a decision on a life's career. The novelist is usually content to assume that there is some mystic element involved, which every one recognizes immediately. He then idealizes that. The occasion for love, again using the novel as a standard, is usually primarily physical beauty, secondarily a congenial temperament or a community of interests.

Fear, Anger, and Hate. — This trilogy of unpleasant emotions has less of general interest, but equally illustrates the difficulties in classification. There is probably a common background in all three of excitation of the sympathetic system, as opposed to the parasympathetic which usually dominates in love. Fear shows more of readiness to flight, or of weakness and even paralysis in pronounced cases than the other two. Anger is marked by more overt bodily activity than hate and probably has more pronounced bodily responses in general. It seems that most classifications of one of these emotions are in practice made as much on the basis of the situation in which the emotion arises and the outcome of the adventure, as of the qualities of conscious character, whether bodily responses or of other origin. During the emotion one is too much interested in other things to consider its qualities. In consequence names are usually given on the criteria of the causes of the emotion or of its outcome.

Rapid Shifts in Emotion. — Perhaps, too, the fact that fear and anger, love and jealousy, and other emotions are so nearly indistinguishable is to be found partly in the fact that one changes into another with great rapidity. Anger is distinct from fear only in the consciousness of power or weakness toward the intruding man or object, and this changes from moment to moment as the situation is faced. One first fears, then becomes angry, and again is afraid, as long as one is living through the experience. When the situation is properly classified, when it is settled that one is stronger and must fight, or is weaker and must run, the emotion is said to take on a new phase, perhaps even to disappear. If one assume a changing response or perhaps a conflict of responses during the emotional state, it is no wonder that the physical accompaniments of opposed emotions should be identical. Both physically and mentally the two fuse, and one may not be sure, even after the event, whether fear or anger was dominant. This rapid alternation of expressions, taken together with the fact that there are always identical responses in the sympathetic or autonomic system, makes classification difficult in practice, and then it is largely in terms of the intellectual antecedents, the nature of the object, and the outcome of the adventure. It is this that led the popular mind and earlier philosophers to the classification of emotions in other than motor terms.

No Complete Enumeration of Emotions Possible. — Beyond the mention of these most obviously different forms of response, a list of emotions soon runs into a series of dictionary definitions. Language distinguishes emotions, among other criteria, on the basis of the time of the stimulus that causes them. Fear of an event to come is dread, an unpleasant attitude towards an event of the past is regret. Different names are given also for the degree of the response, and with reference to the nature of the agent. Hate is always of a person, or of an object personified, while fear may apply to person or thing. Psychology may omit a discussion of these differences as not important for its purposes.

The Occasions of Emotions. — The occasions for emotions fall into two groups. The simplest are sensory stimuli which evoke the pronounced response because of the innate characteristics of the organism and the sudden or unusually intense character of the stimulus. The second is dependent upon the education and the more complicated purposes of the individual. The first may be regarded as an inherited pattern reaction on the same level as the innately determined reactions of the external muscles. In emotion, the groups of responses are internal rather than external, of the unstriped as well as of the striped muscles. In the second group are the stimuli which have an emotional value because of acquired connections. Many of these are due to simple transfers from an original stimulus to others that have acted at the same time. The emotion one experiences at the point on the road where one has been the witness of a fatal accident, for example, illustrates such a transfer. More subtle and general are emotions that arise from furthering and thwarting life's aims and purposes. An event that threatens the secure position one has established may cause greater fear than a threat of physical danger. Suddenly receiving an unexpected honor may cause greater joy than any physical stimulus. Sudden interruption of the trend of the moment by a stimulus in either class evokes a more pronounced emotion than an expected event.

Emotion and Language. — Certain of the emotional accompaniments, in fact many of those that come from the more external and voluntary processes, have taken on a secondary value as a means of communication, as a means of indicating to another the state of one's mind. The facial expressions, as was said, directly convey an impression of the emotion and serve as warning or encouragement to the companions to cease or to continue the line of action that they happen to be pursuing at the moment. It is probable that the beginnings of articulate speech are to be found in emotional expression. Many of the lower animals express emotions through sounds, and it seems possible, even probable, that speech came from the association of some general attitude of the individual making the sound, with the sound; and that little by little other associations came to be made with it until our present fully developed languages made their appearance. We can still determine the emotional tone from the modulations of the voice. The loud tones and marked accents of anger, the dragging monotony of the whine of discontent, the softly modulated tones of affection show the emotional state very much more clearly than can any explicit statement in words. They can be detected easily in speech even in a language that we do not at all understand, and convey almost as much of the emotional attitude of the speaker in an unknown language as do words in our own tongue. It is not impossible that these varying cadences were the primary forms of expression and communication and that the words as they developed have been fitted into them.

Emotional Control. — One may control emotions in some degree. The only real control is that effected at the source. The nature and degree of an emotion depend very largely upon the way a situation is classified. An event frequently may be referred to more than one head and will arouse a different emotion under each of these classifications. A human brain, presented to a class with numerous references to what the individual must have thought with it, and with other remarks that emphasize the personal side, is very likely to arouse intense emotions; but, if considered only in connection with tracts and structure, may excite mere scientific interest. Many of the events of everyday life show the same phenomenon. Classify a remark or the man who makes a remark in one way and you become angry; regard it or him in another light and you are only mildly amused. Much also may be done by preventing expression, although this too can be controlled only by changing the attitude or in directing attention to something else until the occasion for the emotion is past. Either method of control becomes much more effective after practice. Like everything else, attitude and response become habitual; instinctive reactions are changed by habit. The physician or surgeon can look upon patients as cases and neglect the more personal relations. Such professional attitudes are taken by members of nearly all professions with the corresponding development or suppression of emotion and emotional expression.

Possible Injuries from Control. — The control of emotion has taken on new importance with recent advances in the study of the causes of nervous and mental disease. Many of these are closely related to the emotions. According to the Freudian school, all but the diseases directly connected with diseased tissues are to be explained as the result of conflicts between opposing emotions or from the checking of emotional expression by social pressure. Repressing an emotion has as its consequence the dissociation of that experience from the general consciousness, and the repression of the experience into the unconscious which may result in hysteria, with its train of paralyses, anæsthesias, and other defects, or even in the insanities of the dementia præcox group. The extreme advocates of the theory argue that the emotions should be given free rein, that any interference might result in disease or in increasing the liability to disease. Taken in the broadest sense this would be subversive of all discipline and would probably be worse for society than the presence of a few hysterics or even insane. On the other hand constant and unnecessary repression of all emotions, such as is seen in families dominated by a too solicitous mother or overbearing father, can be avoided without any serious social consequences, and may save the mental health of the child. The motto should be free vent for emotions wherever there is not too much injury to others, with discipline restricted to essentials and exercised with as much consideration as possible. Where repression is necessary it should be made to take, as far as possible, the form of a transference to some other object than that usually given it. Control by changing the classification of the stimulus is also relatively harmless.

THE ORIGIN OF EMOTIONS

Emotions Due to Natural Selection. — As with the innately determined pattern responses and feelings, emotions are to be explained as due to the inheritance of useful chance variations in the germ plasm. The utility of some of the emotional concomitant movements is clear. Some of the movements are now merely expressive. Even these are assumed to have been useful once, and now persist, either because of their social value or because they have no tendency to prevent the survival of the animal that retains them. They arose by virtue of the survival of the organisms that developed the responses, or by the dying out of organisms that failed to develop them. A large number of the movements can be shown to be direct survivals of such instinctive responses. Running away, drawing back, or the start of fear, evidently removes the individual from the neighborhood of the dangerous object. Less obvious is the utility of the trembling and loss of strength that come momentarily in fear. This may be traced to a reduced form of 'playing possum' or of crouching and remaining motionless as seen in the rabbit and other defenseless animals. It forces them to remain motionless and thus enables them to escape the attention of pursuers and possible enemies. The cry of the child is similarly useful in attracting attention when it is alone or is uncomfortable. In each of these cases, the conscious state, the emotion proper, is probably of slight value but seems to be an unavoidable accompaniment.

Theory of Transfer of Emotional Expression. — Darwin has suggested that three other classes of emotional expression must be recognized which serve still farther to explain or at least to classify the development of emotional responses.

These are first, that when an emotion or a condition has given rise to one form of expression, a similar emotion or situation will give rise to a similar response. The second is that, granted an original response, an opposed situation will give rise to the opposite response. His third class is that in which certain emotions result from the direct overflow of nervous excitation without any controlling conditions. The first of these laws is illustrated by the sneer, which Darwin refers to the snarl of the dog. The dog when a possible enemy approaches exposes the teeth and prepares for an attack. In man the situation is similar and probably the mental attitude also. In consequence man, too, draws back the corners of the mouth, although there is now no thought of biting. Similarly, in anger, the nostrils are frequently slightly expanded, although there is now no particular utility in the movement. This Darwin would explain as preparation in the animal for admitting air while the mouth was stopped with the hairy body of the antagonist. The expression continues although the original occasion no longer exists. The second class is more open to objection. The best illustrations are furnished by the movements of a cat in expressing friendliness. When angry the cat crouches, keeps the ears back where they will not be in danger of injury; the tail is down and lashing the sides. When pleased, the opposite of this position is taken. She is erect and arches the back, the tail is held high, ears erect. There is no particular reason for this group of responses, and Darwin finds it in the law of antagonism. The mechanism that leads to this opposed reaction is altogether unknown, and, as we have seen in connection with the feelings and in the recent studies of emotional expression, there is no evidence ot a tendency to opposition in the expressions. The third class, of direct overflow, includes all that cannot be explained under the other heads. Of course it is not really a new head, as all are due to direct overflow of nervous energy, and this third class includes only such forms of expression as cannot be accounted for at all. Darwin's instances are not very well authenticated. One was of an individual whose hair turned gray over night when he was condemned to die in the morning; the report being based on the statement from hearsay of a British Indian officer.

Conclusions Concerning Emotion. — We may think of emotion, then, as a disturbance of the usual or normal course of any succession of thoughts or activities by the intrusion of a new or extraneous event. This event results in a more or less prolonged disturbance of the activities, accompanied by many useless and incoördinated responses, and by intense affection. It is possible to distinguish two types of emotion, or at least two extremes of emotion. One, usually the more violent but usually of short duration, is directly dependent upon the innate appeal of the stimulus, both in condition and response. This is the type that may be defined as an innately determined pattern reaction, largely of the autonomic nervous system. The second type, which is usually of slighter intensity and greater duration, is conditioned by the thwarting or furthering of the system of purposes developed by the individual. Even for this class the responses are also innately determined. In this latter case, however, we must look to the mental antecedents rather than to the physical responses as the cause of the emotion, and as the determinant of the type of emotion that shall be induced by the stimulus. The bodily reverberation depends upon the antecedent mental states rather than being itself a first cause and constituting, througn the sensations it excites, the entire emotion. This is not to deny importance to the movements in giving color to emotion; it merely insists that other factors must be considered in discussing its origin.

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Key to Emotions in Fig. 81. *Facing page 298*

1. Mirth; 2. Anger; 3. Fear; 4. Surprise; 5. Contempt; 6. Pain; 7. Pleased surprise; 8. Scorn; 9. Lassitude; 10. Mild pleasure. The first six are better standardized than the others.

CHAPTER X

LEARNING — MOTOR PHASES

ONE of the most important functions of any organism is to vary its movements to meet the demands of the environment and to have these variations retained for future use. It is accepted as a general law that any act modifies the reacting organism in such a way that there is a tendency for the movement to be repeated whenever the same occasion presents itself. The earliest signs of learning are found in the unicellular animals. Jennings, as was seen in Chapter II, reports that a stentor modifies its responses when the first and natural one fails to remove an unpleasant source of stimulation. The amœba gives signs of the influence of earlier upon later acts. These acts are before any differentiation has appeared, and long before there is any sign of a nervous system. It must depend upon a modification in the constitution of the single cell, but what that change may be is entirely unknown. We do not even have basis for speculating about it.

Learning in Higher Organisms. — Signs of learning of the type familiar in man have been studied in numerous invertebrates. Yerkes found that the earth worm could be taught to take one definite path in preference to another. Schnierla has shown that ants may be taught to go without mistake through relatively complicated mazes. All forms of vertebrates have been shown to have the capacity for learning acts suited to their bodily structures. The fish, turtles, birds of various species, and a very large number of different genera of vertebrates have been carefully investigated and all are shown to learn with comparative ease. Möbius and Triplett showed that a pike could be taught by suitable punishment to avoid or at least not to attack a minnow. If the minnow were separated from the pike by a glass plate, the pike would dart against the glass in the attempt to attack. After suffering the pain of the contact a number of times, he would, after the glass was removed, swim about with the minnow without attempting to attack. If the minnow made a sudden movement the effects of learning would disappear and the native tendency to grab it would assert itself. Fish have also been taught to adjust responses to different colors.

Native Responses and Learning. — As was said in discussing native responses, there is a close interrelation between what is native and what is acquired. The animal or man can learn only what the physical endowment makes possible. Learning to fly is not within the physical capacity of the fish or the mammal. Learning other acts may be excluded by the lack of connections within the nervous system. Learning is also dependent upon the appeal of movements and of stimuli of different sorts. Of the movements executed, only those which make an impression because they give pleasure or free from pain will be much more likely to be repeated than those which are affectively indifferent. As was said in connection with the innate movements, learning requires a number of chance or indefinite movements from which the movement to be learned is selected. It also implies certain innate preferences that determine what movements shall be repeated and so stamped in.

Drives in Learning. — Just as the simpler responses are the outcome of internal as well as external stimulations and responses, so in the learning at a higher stage these drives are important. One cannot make a white rat run a maze unless the external stimuli are combined with suitable internal stimuli or conditions. Again hunger, thirst, sex, and the glands of internal secretion must combine to excite the general movement which makes learning possible. To these must be added a general state of well-being which on occasion may induce an animal to run without special goal or special drive. A white rat that is neither sated nor hungry will frequently run a maze out of what the human would call curiosity and may learn almost as quickly as when there is a hunger drive. In general, however, increase in hunger hastens the learning. And having once obtained pleasant food, running will be more rapid than if the food is of a kind less eagerly consumed.

Trial and Error in Learning. — The first experiments which fall within the range of the modern theory were conducted by Thorndike at the turn of the present century. Thorndike worked with cats and dogs and taught them to get out of boxes of which the doors were closed by different types of catches. The animals were put in the boxes when hungry, and were fed when they succeeded in getting out. This, with the objection to confinement, served as the incentives to

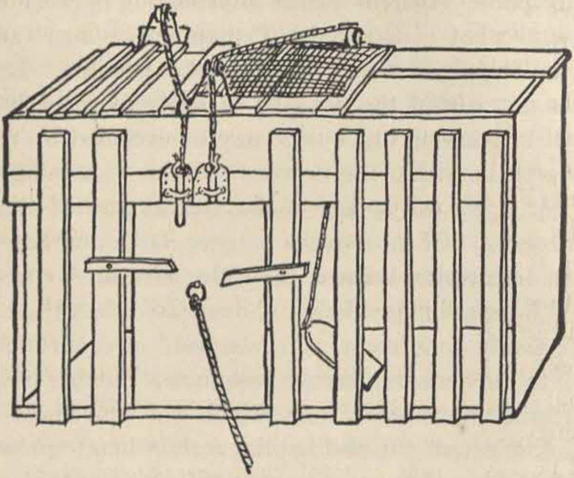

FIG. 82. — Animal problem box. (From Thorndike, "Animal Intelligence.")

the original movements. Thorndike's interpretation of the learning process is that the animal goes through a series of aimless or chance movements, one of which finally opens the door. When put back a second time after eating a little food, the animal will again go through a series of random movements, but on the average each succeeding trial will be successful in a little shorter time until learning is finally complete. If the time required for success at each trial is plotted it will be found that the improvement is rapid at first and then more gradual until the right movement is made at once.

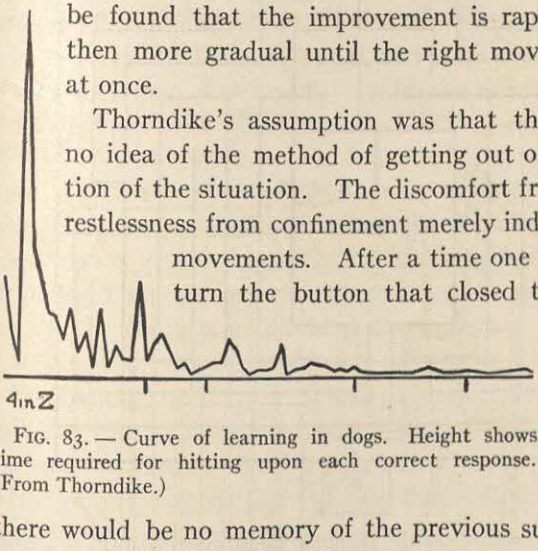

FIG. 83. — Curve of learning in dogs. Height shows time required for hitting upon each correct response. (From Thorndike.)

Thorndike's assumption was that the animals had no idea of the method of getting out or any appreciation of the situation. The discomfort from hunger and restlessness from confinement merely induced a series of movements. After a time one of these would turn the button that closed the door. The door would be pressed open and the cat would walk out. When put back there would be no memory of the previous success, at least no more than of the place where success rewarded the effort. The repetition comes again as a matter of chance. Only the movements that are followed by the pleasure of success will be repeated and so learned. Any movement that is followed by the opening of the door will be established whether it is the real cause of the opening or not. Thus if the door is opened whenever the cat licks itself, after a sufficient series the licking will be the first movement made after being put in the box. Other experimenters have shown that the cat may open the door without noticing it and so fail to walk out. In this case we deal with the establishment of a single connection between a group of stimuli and a short series of movements.

Maze Learning. — More used in recent work has been the problem of teaching the animal to find his way through a maze. This offers a chance to study a series of movements that must be combined into a single pattern. The mazes may be as complicated as is desired. Care is usually taken that no simple habit such as of alternate right and left turns will lead to the solution. White rats are usually employed. They are put into the maze at the entrance when hungry, and food is placed in the end compartment. Record is kept of each turn made, so that all errors may be noted. There are always a number of blind passages, or passages which lead to long and devious wanderings. At first the rat wanders some-

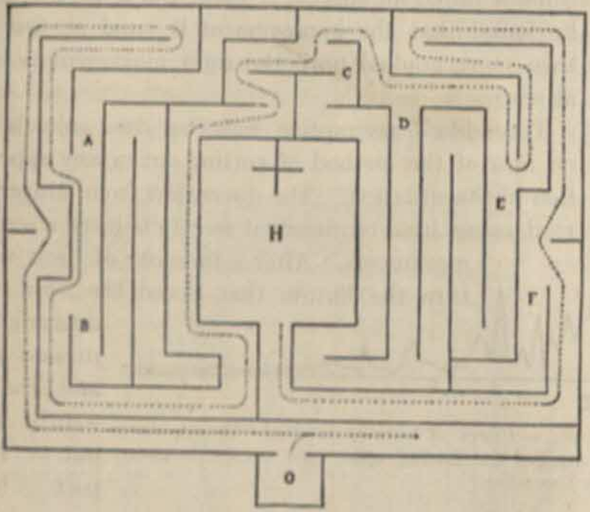

FIG. 84. — Maze copied from the Hampton Court maze, adapted to animal learning. The animals are put in at O and must find their way to H, where they are fed.

what aimlessly, explores the blind passages, and comes back to the main path. Gradually with repetitions the blind passages are not entered and the longer passages are omitted in favor of the more direct path. When learning is complete the rat runs through by the shortest path with no false turns.

Patterns in Learning. — A study of the details of the learning throws much light on the mechanism. We find here, too, evidence of the importance of the pleasure of the reward upon the quickness of forming connections. The first errors to be avoided are those nearest the food box. Next are those at the beginning of the maze. Last to be discarded are the false turns in the middle of the maze. The learning cannot be explained as due merely to the frequency with which the different parts are repeated together or are connected, for the rat omits entering the blind passage that he has gone into most frequently. Partly this might be due to the unpleasant effect of finding himself blocked. There is other evidence that not merely the contiguous parts of the path are connected but that the whole comes to form a pattern in which each step influences every other part. The parts that fail to fit into the unit are gradually eliminated. This accounts, too, for the gradual elimination of the longer of two possible paths, even if the longer happens to have been first entered and to have been run through repeatedly.

The influence of either a general awareness of direction, similar to that which a man shows in a strange city or new forest, also seems to show itself in the rat. If he is shown a bit of food in one of two food boxes and then is put in a maze which leads equally well to either, he will thread the paths towards the one where the food has been seen rather than towards the other. Then, too, if a path has been used to the food box, and is then closed and replaced by a long detour, when the rats reach the place where the old path started, even if the wall be entirely smooth, they always stop and smell about for a time before they will take the detour. These both indicate that the rat has not merely a series of connections between part and part, but also a notion of the whole and of general directions. All of these facts show that, while originally learning may be merely forming connections between one stimulus and a single more or less complicated response, even forming this connection may depend upon the after effects of pleasure. More frequently a chain of responses, each of which is dependent upon the others, becomes connected into a pattern and is learned more or less as a whole.

Insight in Animal Learning. — To complete this statement of theories of animal learning, one should mention a variant from the explanation here given. This was suggested by Köhler and is in a sense a return to the view held by the popular mind before animal experiment began. Köhler performed a number of experiments upon chimpanzees and was struck rather by the definiteness of many of the movements they made and the immediateness with which they reached their goal than by the chance character of the responses. At times his chimpanzees would suddenly put together two pieces of bamboo to make a stick long enough to reach a banana in front of the cage. Or they would suddenly begin to bring boxes and pile them one on the other to make a perch from which a banana at the top of the cage could be reached. All of these were assumed to be cases in which the ape thought first and acted later. He saw the situation as a whole before he responded. This view was emphasized by the fact that the act was frequently preceded by a period of quiet with fixed gaze that was interpreted as consideration.

Adams repeated Thorndike's experiments with cats in the light of Köhler's results and came to the conclusion that cats, too, thought out their acts in advance. They, too, spent a little time in contemplation before they went through the movements that freed them from the cage with puzzle locks on the doors. These conclusions raise an interesting problem as to whether we can safely argue from the attitude of the cat or the ape what his mental processes really are. If there is insight, it can come only in flashes. There is relatively little evidence in the curves of sudden learning. The laws of chance would require that at times the first response would be the correct one. One needs a high percentage of immediate successes before one can safely infer that they are the result of previous calculation. The evidence is not yet conclusive.

Insight has been used to designate a slightly different process in maze running. Maier and later Tolman and his students have used it to indicate the ability of the rat to find his way to a goal on the basis of general direction mentioned above. Maier used the term to designate the ability of the rat to go directly to the food after having been shown it once. Tolman gave rats a number of runs through a maze and then left them free to choose between the path they had practiced and a more direct one. In a number of instances they chose the direct path, which had not been previously followed, in preference to the familiar one. The apparent immediate orientation or general notion of direction is cited as evidence for the efficacy of insight.

The Definition of Insight. — For Köhler, who first used the term, the implication was that insight meant appreciation in terms of the whole. The animal saw the particular problem in the light of a purpose and the general situation. This relation to other features of the whole was assumed to be the determining factor in the solution. This is still more obvious in finding the way to a food box without reference to earlier particular connections. The rat does not go from turn to turn, but develops a general notion of a direction which leads at once towards the goal. In both uses insight is not analyzed. It is a term to indicate that something more is developed in learning than the formation of a series of connections. The implication is that the animal thinks in much the same way man does. However it is not said how man thinks, which is itself a difficult and not altogether solved problem, as will be seen in a later chapter.

The Conditioned Reflex. — The Russian physiologist, Pawlow, has introduced an experiment and a term that would represent the learning process much more simply, in fact in its simplest terms. Pawlow's experiment consisted in showing that a reflex response which was natively aroused by one stimulus, might by training be induced by another stimulus which was by inheritance connected with an entirely different reflex. As his first reflex he chose the production of a flow of saliva by a meat powder placed in a dog's mouth. To make possible exact measurement, the duct that leads from the parotid salivary gland to the mouth was dissected out and brought outside the cheek so saliva would drip into a scale pan. The amount of the dripping could then be recorded upon a kymograph, or weighed. Just before the meat was put upon the tongue a bell was sounded. The experiment was repeated a few times. It was then found that when the bell was sounded without the meat, saliva would flow. This was called the conditioned reflex, and transferring the effects of one stimulus to another was called conditioning.

Limits of Conditioning. — The circumstances under which conditioning may take place have been worked out at great length. It is found that an animal can become conditioned only to stimuli that are given before the stimulus that naturally calls out the response. It also cannot precede it by more than thirty seconds. The transfer will not take place if other stimuli are distracting the dog at the time. The Behaviorists have made much of conditioning since it gives them an explanation of learning without assuming any consciousness of the stimuli on the part of the animal that learns. Pawlow assumed that the connections were formed in the cortex since an animal without a cortex showed no signs of conditioning. Simultaneous action of two stimuli upon the cortex was supposed to transfer the motor connections of the originally exciting stimulus to the other one that acted at the same time. Experiments upon men show that similar connections can be formed for them. The salivary reflex has been transferred in the child from chocolate taken into the mouth to a sound. The wink reflex has also been transferred from light to the sound of a bell. Granted the conditioned reflex, the feeling and emotional responses may be changed from any stimulus to any other. This complicates the problem of determining what the original appeals or responses may be. It is important as emphasizing the value of learning.

Learning to Speak. — Human learning shows very much the same tendencies as animal. There must be a variety of movements, forced or spontaneous, from which to select and there must be some feeling response to one response or its results rather than to another that determines which shall be repeated. The process of learning to speak is typical. The child has no innate capacity for learning one language rather than another. It merely makes one sound after another because of the overflow of sensory stimuli of an undetermined sort upon the organs of phonation. When a sound comes that strikes its fancy, that sound is imitated and the movement of imitation will be repeated and so gradually established. Hearing the words of parents and older children serves to impress them upon the child and so make them interesting. When by chance one of its own vocal efforts approximates one that it has heard, it is repeated. The approval of parents that greet this word and the advantages that come later from social communication lead to a continuance of the repetition until real speech is developed.

It has been shown by Spaulding and others that the songs of birds are similarly acquired from what may be called imitation. Imitation is, however, not conscious or intentional, but a mere repetition of the sounds the nestling makes by chance which happen to resemble those of the birds about it. The songs that are learned are the songs of the birds with which it is reared rather than those peculiar to its species. If a sparrow be reared with Baltimore orioles exclusively, it will acquire their song, or an approximation to it. The original sounds are determined by the nature of the vocal organs and by the possible motor connections. The selection from these possible tones is in terms of the immediate appeal as when the child repeats a soft cooing. Learning to speak comes because the child is struck by the tones among those it makes itself which resemble the sounds it hears from its parents.

Learning a New Movement. — Other movements, such as walking and the first movements of the hands, come in the same way. First they are made by chance and the effective ones are selected. When a fairly complete repertory of movements has been developed, they may be transferred to new uses, and combined indefinitely. Starting with simple movements, one combines them to make patterns and then these patterns are treated as single movements. This is what we call habit formation, cases in which one movement follows another with little notion of the occasion and no awareness of the completion of one part and the initiation of another. Through frequent repetition most acts of daily life have been reduced to these simple patterns. In dressing the single acts are combined so that one follows another immediately and without being noticed. Many of the social greetings go on just as mechanically. They are responses in which seeing the other man is the stimulus. Reduction of the frequently repeated processes to unitary patterns saves time and thought.

Learning as Spreading of Impulses. — Learning an entirely new movement in an adult follows much the same pattern. Bair long ago investigated the processes involved in learning to move the ears. In man there seem to be no connections fully developed between any sense-organ and the ears. It is only rarely that a man moves his ears and then as a result of special training. There are no reflex responses of the ears. Still the muscle that pulls the ear back is fully developed and has some connection with the central nervous system. Bair rigged up an instrument to attach to the ears that would move a lever on a kymograph and give a record of each movement. The observer was asked to try to move his ears during one period. Then an electric current was applied to the muscle which produced a contraction repeatedly during a second period. In a third period he was asked to attempt to move the ear as the current was applied. In a fourth period he was asked to prevent the ear from contracting as a series of electric shocks was given. The results showed that moving the ear by the electric current was not an aid to learning. The observer learned just as fast without it. What proved to be the successful method was to make various grimaces, moving the jaws in awkward ways, wrinkling the brows, etc. The nerve impulses involved in these movements at times would overflow into the nerve leading to the ear. When the ear moved by chance it was noted and the movement could occasionally be repeated, although the observer reported at times that the experiment was like trying to open the door without touching it.

The whole process was as much a process of trial and error as the movements of the cat in getting out of the box. It seemed to be merely blind trying. Only gradually did the observer become aware of the successes. Finally the voluntary movements became as marked as those produced by the current. Two incidental evidences of the degree in which the observer was unaware of the process may be mentioned. The first was that when the attempt was made to prevent the ear from contracting, it was held contracted during the entire period to the maximum possible at the stage of learning. Intention not to contract had the same effect as intention to contract. The second indication of lack of control was that both ear-muscles contracted at the same time although the plan was to move but one. It was noticed by chance that both ears were moving. This again is a primitive phenomenon. At first the infant moves both hands and even both feet symmetrically. The hands move in and out together as if by a common impulse. If a child is asked, after he has learned to write, to write with his left hand, he writes most easily in mirror writing, that is, in writing that can be read only in a mirror. The two ears moved together in the same way without any awareness of the symmetrical spread of the impulses. When attention was called to it and the observer asked to move one ear alone, he succeeded. He did it by thinking only of the one he wanted to move and neglecting the other. Learning of all types is thus a process of developing chance movements into orderly connections by selection of the appropriate movement when it happens to appear.

Changing Paths in the Central Nervous System. — This still leaves open the question as to what brought the so-called chance response in the first place. If we turn back to the nervous system, it may be said that a given sensory impression stimulates a sensory neurone, which in its turn has axones connected with a number of motor neurones. The synapse to one of the motor neurones probably offers least resistance and the impulse passes across that. If the result which comes from the act gives pain or does not remove the unpleasant stimulus, a new set of responses will be started as the stimulus becomes strong enough to open less permeable synapses. If, for example, the cat does not escape, get the meat, and in consequence begin the instinctive responses involved in eating, then new synapses will be opened and other movements result until some change in the stimulation starts a new series of responses. It should be remembered that there is not one stimulus but many, and that, as attention changes, new stimuli come which also make possible new movements. When any movement has been made, the same stimulus will produce the same movement, and each repetition reduces the resistance at the synapse as in the formation of association. In animals and in the ordinary learning of man, each movement is the result of instinctive responses or of earlier habits. Watson once asserted that there is no real formation of new connections in learning, but that all is due to the elimination of certain of the unnecessary movements in the first trials. His theory is that the inherited connections usually offer roundabout paths between stimulus and movement. This series of responses is innate. Trial and error finally make a more direct connection between the stimulus and the successful act. On this theory learning could never lead to absolutely new connections. It could only shorten the course. Undoubtedly a large part of learning is of this character. Watson has more recently taken the opposite view. He asserts now that all is learned and there are no inherited connections.

To What Extent Are New Connections Formed in Learning? — In man, however, there seem to be cases in which there is no natural nervous connection at the synapses, or at least in which the instinctive connection is very weak, and in which learning takes place through a spread of impulses over synapses very slightly permeable. Thus, in learning to move the ears in the experiments that Bair carried out, a connection was formed, a path of discharge was opened to a muscle not ordinarily under voluntary control. Here there seemed to be a gradual spread of impulse from the usual channels to more and more unusual ones, until finally it chanced to find the old path to the *retrahens* muscle, the muscle that pulls the ear back. Then repetition stamped in the connection until it could be repeated at will.

Another case of the formation of new connections is furnished by the surgical operation that replaces an impaired nerve by another with an altogether different central connection. Thus, when there has been paralysis of the nerve innervating the flexor muscle of the arm, it has been possible to divide the nerve supplying the extensor muscle and connect one part of it with the injured flexor muscle. When it has regenerated, the nerves that previously produced extension of the arm now carry the impulses which produce flexion. Here evidently we cannot be dealing with a dropping out of old connections but must have the formation of altogether new ones. Even more convincing are the experiments and treatments of Lashley and Franz. They showed that a monkey which had had an arm paralyzed by extirpation of the controlling area in the cortex would completely recover the use of the arm if forced to use it, although there was no regeneration of tissue. Constant trial induced similar recovery of function in men in cases of long-standing paralysis due to disease. These paralyses must be overcome by the opening of new connections between sensory and motor neurones by the process of trial and error. All three instances involve formation of connections that are not definitely present at birth; in the second instance, in fact, they follow paths and produce movements, the reverse of those that are innate. Indeed, much evidence is accumulating that there is considerable variation in the paths followed during the same function of the cortex. If confirmed, this fact would prove that the formation of new connections is the rule rather than the exception.

The Acquisition of Skill. — In the adult man the most important practical aspect of learning is that series of acts, already under control in isolation, may be united into a single series, and made to constitute a unitary group. This is what happens when one acquires skill in any game or occupation. A number of investigations have been carried out on problems of this sort. Bryan and Harter[1] investigated the learning of the telegraphic language; Swift[2] studied typewriting, tossing balls, and learning Russian; Bair and Book investigated typewriting; Snoddy used writing from a mirror image for his learning. All obtained the same general result, that skill comes rapidly at first and then more slowly, and that in the course of the work there are many periods in which no progress is made, followed by periods of rapid improvement. In each of these tasks the individual movements are known in advance. One can press the key of a telegraph instrument or of the typewriter or toss a ball at the start. What is necessary is to organize a whole series of movements so that one element shall start the next, and all shall be carried on together without false movements, and as rapidly as is possible. All agree that improvement here, like the original learning, comes largely by chance successes. One hits upon some more effective combination of movements without any definite foresight, and even without knowing what it is that causes the improvement. The worker does his best all along, and at times an improvement comes, at times it does not. There is always fluctuation from day to day. This seems due in part to the general physical condition, in part to chance changes in the character of the work. The preliminary feeling offers little or no indication of what the course of the work is to be. One may feel well, even feel certain that a good score is to be made on a certain day, and find that the accomplishment is lower than on days when the general feeling seems to offer less hope of success.

Plateaus in Learning. — Many investigators have found that for complicated acts, there are likely to be periods during the learning in which no progress is made. The same amount of effort is exerted, and all the conditions seem to be approximately the same, but no progress results for a long interval. Various explanations are given for the periods of no progress

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[1] Bryan and Harter, "Studies on the Telegraphic Language," *Psychological Review*, 1897, p. 27.

[2] Swift, "Acquisition of Skill in Typewriting," *Psychological Bulletin*, vol. 1, p. 295.

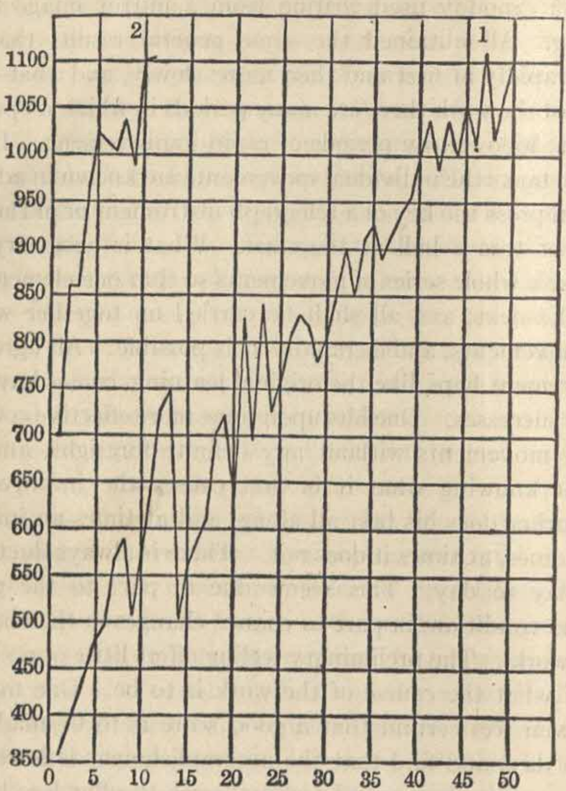

FIG. 85. — Curve of learning to write on the typewriter. The horizontal distances show the number of days of practice; the vertical, the number of words written in an hour. Curve 1 shows the progress during the original practice; curve 2, the results of nine days' practice after an interval of two years and thirty-five days. (From Swift.)

which have been called plateaus. Bryan and Harter assert that plateaus are periods in which the old associations or partial habits are being more firmly implanted, and that this is essential for any farther advance. In certain cases this seems true. It has also been asserted that they are periods in which the worker loses interest and relaxes effort, but most workers do not accept this as a general explanation. The plateaus are also found when effort is kept at a maximum. Assuming that the plateaus are necessary as preparation for a new advance, the reason for the rise to a new level offers difficulties. Three explanations have been suggested. (1) The simplest is that the preparation has been completed and then some new combination of movements is hit upon that makes the progress possible. (2) Even Bryan, who argues that a plateau is a period of preparation for increased efficiency, insists that there is often at least some special stimulus. He quotes instances of telegraphers who have spent some time in a small office who show a sudden rise in ability when transferred to a main line office. Here increase is probably the result of new incentives. (3) A third important factor lies in becoming clearly aware of the conditions of the problem, of what must be done to gain full control, — with this there is frequently an increase of skill. Effort may be helpful or may not, according to the time at which it is exerted. If all is ready, increased effort may give increased effectiveness; if the effort comes too soon, it may be a detriment and even lead to postponement of the advance.

Plateaus Due to Development of a Single Pattern. — Many more recent workers have found that plateaus do not appear if the movements to be learned are of the same kind. They appear only when movements of a markedly different character need to be combined into a single pattern.

Batson [1] carried out an investigation of the learning process for tossing balls. His conclusion is that the plateaus are the expression of the time taken to associate several movements into a chain, when the separate movements must be combined into a unit before new progress is possible. Thus, keeping two balls in the air with one hand requires three separate acts: estimation of direction, estimation of the right height to throw the balls or of the force, and estimation of the time required for the balls to rise and fall, since the ball is seen only at its highest point. Unless these three acts could be made together, no real progress was possible. The plateaus were thought to correspond to the periods during which the three factors were being combined, or during which each was being learned separately before they could be combined. If the act to be learned was simple, involving only one process, no plateaus were found. If attention was distributed over the entire process, if all three part processes were attended to at all times, the plateaus were not so likely to appear. In Batson's experiments they were found only in composite acts where the parts were attended to separately and then joined into groups.

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[1] Batson, "Acquisition of Skill," Monograph Supplement, *Psychological Review*, vol. xxi, 1916.

Other men have obtained the same general results, and have given approximately the same explanation under different names. Recently the formation of a whole or Gestalt, as opposed to learning separate habits, has been emphasized. Wheeler calls it irradiation. Whatever the term applied, all seem to agree that there is a hesitation in learning when simple series of movements or small patterns must be combined into a unitary larger pattern.

The General Problem of Skill. — Acquirement of skill in any one act is typical of the general laws of habit formation. The earliest combinations are made on the basis of innate connections, and the movements themselves are evoked by stimuli. Learning is the result of selecting the movements that have a pleasant effect. Acquiring skill, in the adult man, usually develops under the influence of a purpose, and is based upon using the movements that have been learned in other connections, as well as the innate ones. In these more complicated and intentional acts, there is much that is uncontrolled. The best combinations seem to be hit upon by chance. It is also true that the person who does the most rapid work is often unable to say how his movements differ from those of the slower worker or from his own at the early stage of his learning, when he was much less efficient. In factories, it is necessary to take motion pictures of operatives at work to learn how the slow differs from the faster worker. The attainment of speed consists in gradually developing patterns of wider and wider reach. In the patterns the narrower are subordinated to the wider. The wider and more inclusive dominates and controls the narrower.

Habit. — The final outcome of all motor learning is the formation of habits. Habit is an acquired tendency to respond to a stimulus that would not earlier have evoked that particular response. On its nervous side habit formation may be regarded as making connections between sensory and motor neurones. These connections once formed persist with decreasing force indefinitely or until that particular stimulus becomes connected with a different movement. These connections when established furnished a foundation for new connections and are constantly being merged into new acts or patterns of acts. The general rule is that one is aware of acts when they are first performed. Later they become mere matters of routine and may be executed without being noticed, even without having the occasion for the act noticed. If as one leaves a room at night one usually turns out the light, one may, on leaving the room in the full light of day, turn on the light and leave without noticing the effect. As a means of saving time and effort for more important things, habit is of great practical utility. Theoretically habit is of the greatest importance. It is a change wrought in the organism by action which modifies the capacities of the organism. This retained modification constitutes part of the endowment.

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CHAPTER XI

RECALL — ITS CONSCIOUS ASPECTS

The Practical Functions of Knowledge. — A new problem now meets us. This is the problem of knowledge in its widest aspects. From the conscious side knowledge is all embracing. It involves the appreciation or construction of the objects in the outside world and of the world itself so far as that is different from objects. The functions of knowing may for purposes of discussion be conveniently divided into three. Knowing objects as actually present to the senses; knowing events not at the moment present to the senses; and making new constructions. The first we designate perception, the second, memory, and the third reason or imagination, according as the constructions are regarded as essentially true or as indifferent to truth.

The Primitive Functions of Knowledge. — Contributing to make possible these practical functions of knowledge are three primitive factors or minor functions. The first of these is retention with the complementary function of recall, as applied to simple sensory experiences. The second is the function of selection. This is seen most simply in the predominance of a few of the many stimuli presented to the senses or pressing for recall, or the favor shown to the momentarily important *figure* as opposed to the *ground*. The third function is representation or meaning. Any mental content is important not for itself but for that for which it stands. This reference is the real thought. The last two have been referred to as dependent upon belonging to a wider whole of mental states.

These three primitive functions are implied in and make possible the more concrete functions that are more frequently mentioned, perception, memory, and reasoning. Things are known only as they are interpreted in the light of earlier experiences; both the phases seen and the interpretation to be put upon them are the result of selection. Perception is always of meanings and types, never of mere sensations or stimuli. The percept is a thing because it is a part of the whole. Memories, although essentially recalled experiences, are selected from the possible events that might be recalled much as stimuli are selected. The events are always merely meant or referred to; they are not reinstated. In reasoning a man deals primarily with meanings and references, rather than with concrete material, but in his constructions uses retained materials and manipulates them by many complicated processes of selection. Imagination is very similar to reasoning. It differs from it only in that the material is a little more concrete, the demands of absolute truth are not so rigidly recognized and adhered to. It also deals primarily with recalled material, selected from the stores of the individual, and always uses them as representative. While these four main functions of knowledge may be recognized, they are not distinct. They are each dependent upon the same three primitive functions of recall, of selection, and of reference to and dependence upon a wider whole.

Structure and Function in Knowing. — Knowledge depends to a degree upon what may be called the material or content of knowledge as well as upon the primitive functions. When a man sees a cube he is aware of a series of two or three surfaces, one possibly nearly square, the others bounded by converging lines. To these may be added a memory image of the other three sides that are not seen. Or he may neglect the surfaces he actually sees with their slanting boundaries and see only three square surfaces. He supplies the sides he does not see almost as definitely as he does those that are presented to the eye. The sensations actually seen are the definite structures. Just as truly structures are the hidden sides which he supplies from memory. As opposed to these the fact that he sees the whole cube in right angles rather than in perspective verges towards function. If he clearly imaged the six sides, that image would also be a structural element. If he was merely aware that what he saw stood for a perfect cube without picturing it, he would be dealing with a pure function. Probably in practice, one never divorces structure from function. There is always a mixture. In recall or in planning a building or instrument, one might just think "a cube should go there" and have no picture at all. The reference would be to the function alone. Even then there might be a word or a symbol. This then would be the structure, but what the structure was would be almost indifferent to the function. A word in any language he knew would do as well as another, and any symbol for a cube that he might have developed for himself might replace all images. Briefly then the sensations and the recalled sensory images constitute the structures that are used in knowledge. Representing actual things and events constitutes their function.

The older psychology was more interested in structure than in function and in many cases tried to solve problems of function by enumerating structures. Even if the functions are made primary, it is necessary to deal with structures as well. In some cases structures place limitations upon functions, in others they explain the functions. We may restrict ourselves in this chapter to a study of the structural phases of the recall of experiences, and neglect the functional aspects. Regarded in the simplest way, all of the memory processes may be thought of as sensory experiences which have been retained and are reinstated on the cue of some new stimulus. The primary qualities are like sensations. No absolutely new qualities can be imagined. Speaking generally, the qualities of memory and imagination are the qualities of sensation. It is possible to go farther and assert that if one is to have in mind images of a given quality, one must at some time have had sensations of the corresponding quality. Individuals blind from birth cannot imagine colors; even the color blind cannot picture the colors which they cannot see. The same holds for all other senses. This has led to the general acceptance in modern times of the statement that all images are derived primarily from sensations. This simplifies our discussion to an investigation of how the original impressions are retained, how they may be rearoused as occasion demands, and how their qualities differ from those of the original.

The Nature of Retention. — Before asking how memories are retained we must inquire where they are retained. Two possibilities have been suggested in the history of the science: one that they are retained in mind or as mental states, the other that they are held in the nervous system. The latter view is at present generally accepted. The theoretical objection to thinking of memories as retained in the form of mental states is that mental states are by definition conscious, whereas actually there is no awareness of memories until they are revived. The individual cannot tell that he has a memory, until he tests it by trying to call up particular facts. On the positive side, the evidence that remembering is in some way dependent upon the nervous system comes from pathology. Numerous mental defects present themselves in which loss of memory is one of the prominent symptoms, and these usually show, on examination of the brain, injuries of portions of the cortex. Destruction of the area corresponding to a sense brings with it loss of the corresponding memories; destruction of neighboring areas or of paths of connection with other portions of the cortex also destroys or impairs the effectiveness of recall of the images. Studies in mental pathology have convinced psychologists that memory processes are closely dependent upon the nervous system.

The methods of retaining memories offer more room for discussion. Various theories have been suggested, from the crude theory of the Greeks that memories were imprinted on the brain or soul, as the impression of the seal upon wax, to the scarcely less crude anatomical theory that each idea has a cell in the brain in which it may be stored. At present the tendency is to find analogies that shall be within the possibilities of the nervous system, and not to make the explanation more specific than the known facts warrant. It is asserted that retention is a result of the activity of the nervous system, it is not a mere passive holding of ideas. Hering was among the first of the modern writers to suggest this method of approach, in stating that memory is a universal property of matter. Any change that may be suffered by any substance tends to persist. Garments wrinkle where they have been often creased; the folding may be said to be 'remembered' by the garment. Scars on the skin, even nail holes in boards, are memories, according to Hering. Semon, a German botanist, has shown that plant tissues change as a result of stimulation and retain the effects of the change to show them again either spontaneously or as the result of new stimulation. The persistence of the effects of an injury to a tissue in the human body, or even the strengthening of a muscle of the body may be brought under the general head of memory in this sense.

Retention and Habit. — In the previous chapter we have demonstrated that learning a movement involves making a connection in the nervous system that persists and shows itself by a tendency to repeat the movement on a similar occasion. Retention of sensory impressions may be regarded as a similar change in the central nervous system. After a group of sensory neurones has been stimulated by an object, these neurones are modified in themselves or in their connections in such a way that they have a tendency to respond in the same way again. When they act again they give rise to a memory image. Just as habit is primarily a process of forming connections between neurone groups that were not connected at birth, so learning of a sensory sort is probably for the most part due to the formation of connections between nerve elements. These we know as associations and shall discuss more in detail later the theories of how they are formed.

The Localization of Engrams. — Semon uses the term *engram* for the change wrought in any living tissue by stimulation. The term is convenient since it does not imply anything concerning the character of what is left. Especially it does not imply that what is retained is an image. In theory it would seem that the engram must be retained in the tissues that are active at the time of the original impression. For the nervous system, this would mean that sensory impressions are retained in the sensory parts of the cortex. Lashley's experiments with rats, it will be remembered from Chapter III, indicated that there was no special part of the brain involved in acquiring or retaining a habit. If a rat had learned a special maze or other puzzle, removing any part of the brain would be accompanied by loss of ability to repeat the act. He might learn the act or another similar one again, but the engram of the habit was destroyed by removing one part of the brain as completely as by removing any other. Observations on men who have suffered loss of memories seem to give more evidence of a specific place for the engram. A patient who has lost specific memories for considerable periods of his life through a tumor in the occipital lobes, is said to have the visual memories restored by the removal of the tumor. More observations are necessary before the question can be regarded as solved. We are probably safe in saying that the engram is retained in the tissues involved in the original act, however widespread the tissues may be that were involved in the act.

After-Image, Memory After-Image, and Memory Image.—If we look at the conscious side of the retention process, it is possible to trace an analogy to the persistence of the effect in the sense organ, the positive after-image of the eye, *e.g.* In vision, gradations may be traced between the after-image and memory images. If one look for a moment at a bright object, the sensation lasts for a short time after the stimulus is removed. This is the visual after-image. It is a persistence of the process in the retina. It moves with the eyes, and is larger, the more remote the surface upon which it is projected. The simplest of the remembered processes is so like this that it is called the memory after-image. It is of considerably longer duration than the retinal after-image, does not move with the eyes, and is known to have its seat in the cortex. If you will glance out of the window and look away or close the eyes, you will retain the details of the landscape in as great detail as when looking at the objects directly. You can study this for four or five seconds and be perfectly sure that the observation is accurate. This process is known as the primary memory, and is probably partly identical with what Fechner called the memory after-image. It is sufficiently distinct to be used for all purposes in place of the actual sensation, and is for many purposes even more effective than the sensation. It may be regarded as due to a persistence of the activity of the cortical elements involved in sensation in just the same way that the after-image is a continuation of the action of the retinal elements. The cortical cells have even greater inertia and so act for a longer time than the rods and cones. A memory, on the same analogy, is merely the reinstatement of the primary memory image after the lapse of a longer or shorter period. The same nervous elements may be assumed to be active at the moment of recall as in the original stimulation, but they cease to act or at least cease to produce conscious processes for a longer or shorter time, and then the activity is in some way reinstated. The three — after-image, memory after-image, and memory image — all exhibit many of the same laws, and may be regarded as successive steps in the same series. The after-image is the persistence of the effect in the sense organ; the primary memory, a persistence of the activity of cells in the cortex; memory, a reinstatement of the activity in the cells of the cortex involved in the primary memory.

The Eidetic Image. — Closely related to the primary memory, probably only a special case of the primary memory, is what Jaensch calls the *eidetic* image. Jaensch found that many children and a few adults have persisting images of an intensity almost as great as the original sensations. If you ask a boy to describe an object he has seen some time before you may see that he looks towards a definite part of the field as he gives his description. If you can succeed in persuading him to describe his images he will tell you that they change their positions arbitrarily, or that they persist in staying in the same position in spite of all efforts that he may make to change them. His images resemble in every way a painting or even a real object. They are also in one type of individuals like after-images in that they seem to be projected outward and change their size with the distance to which they are projected. Project the image of a dime on a paper at the distance it was originally seen, it will be the size of a dime. Project it on the wall ten feet away and it will be as large as a dollar. Eidetic images also are usually seen in their true colors. Jaensch found that many children have these eidetic images in marked degree until their early teens and then gradually lose them as they pass into the adult period. While they retain this capacity, they are extremely accurate observers, they can draw accurately from memory, if they have sufficient motor skill; as we shall see, their memory of rote material may improve for a time after they have ceased to repeat it. This point will be considered in more detail in the chapter on memory.

Perseveration. — If we assume that an engram is left on the central nervous system by each stimulation or response, the question is still open as to how and when this engram gives rise to an image. Obviously the engram itself is usually not in evidence. Every man has myriads of engrams of whose very existence he is not aware. They represent only potentialities of images or of motor responses. Specific occasions must act before these potentialities are realized. Two ways may be recognized in which the engrams become evident — by perseveration and through associations. Perseveration is less evident, less generally accepted, although theoretically simpler than association. It is merely an instance of the memory after-image, a continuance unchanged of the original stimulation. The term was introduced by Müller and Pilzecker to explain certain results in memory experiments. Their picture of the process was that when an impression has been made, the nerve cells affected continue to act for a time, and in consequence, the corresponding ideas are likely to force their way into consciousness when nothing else offers, or to combine with other processes active at the same time in the production of more complex processes. Instances mentioned are the reappearance of words that have been heard or spoken just before, but have no noticeable connection with the course of thought; the tendency of tunes to 'run in the head'; of complicated practical problems to keep returning to mind on all occasions, etc. This tendency seems to decrease rather quickly at first, but some slight effect apparently persists for hours, and when the original event is interesting or the impression strong, may last for several days. It is assumed that the activity of the nerve cells is continuous, but that the effect of their activity rises to consciousness only now and again. While the perseveration tendency itself is unquestioned, how long it continues and whether the reappearance of the experiences is due to it or to unnoticed associations are matters of dispute.

ASSOCIATION

Association. — The second method of reinstating old impressions on the basis of the engram is by what is known as association. Briefly stated, the law of association is that an event will be recalled whenever one has been thinking just before of another event that was previously experienced at the same time with it, just preceding it or that has some similarity with it. This law was formulated in almost the form we give it today by Aristotle, and many still earlier writers had suggested it. The chance observation of the way ideas recurred led to the early formulation of the law. It was relatively rough in method but gave a fair agreement with the results of the more refined experimental methods used recently. Experiments have been devoted to determining how and under what circumstances connections may be formed between stimuli, how they persist, and the conditions under which one leads to the recall of the other.

Classification of Associations. — We may follow the course of the original discovery and consider first the way words are recalled when a word is heard. Kent and Rosanoff developed a test for determining the recall of words in the insane as compared with the sane. They merely chose a thousand people at random, and without any previous study of the way these individuals had developed the associations, asked each of them to give the first word that came to mind after a word was shown. They obtained a thousand responses to each of a hundred words. Many of the responses were common. Thus to *man*, 394 responded *woman*, 99 *male*, 30 *strength*, 44 *boy*, 30 *person*, etc.; to *mountain*, 246 responded *high*, 184 *hill*, 73 *height*, 90 *valley;* to *soft*, 365 responded *hard*, 53 *pillow*, 34 *easy*, etc. If one will permit the train of ideas to wander uncontrolled for five seconds and then write down the ideas that present themselves, similar connections can be traced

The connections in these cases may be classified under the traditional four heads, — contiguity, succession, similarity, and contrast. In the given list of words it will be seen that all the connections can be traced to one of these groups. Soft and hard, mountain and valley, man and woman, may be classed as contrasting; hill and mountain, soft and easy, man and male, may be regarded as similar; soft and pillow, high and mountain, man and strength, as connected through verbal succession or by contiguity of the objects.

It should be noted that this is a classification of the connections after they have been formed, and is made after rather than before the fact. It is a classification of the relation the ideas hold to each other, rather than a statement of the causes of recall. Even so far as it holds, it is not altogether unambiguous. Mountain and valley are contiguous as well as contrasting, man and woman, as all contrasting things must be, are in some degree similar; they also are frequently found together and the words have been many times repeated in succession. For the real cause of arousal, we must turn again to the neurones that are involved in the activity.

The Formation of Association. — More study has been given to the way in which associations are formed. The general law as usually stated is that any two events which occur together or in immediate succession tend to become connected in such a way that one will recall the other. It has been shown that in learning nonsense syllables, the more frequently syllables are repeated the stronger is the bond as measured either by the number of repetitions needed to complete the learning or by the number of mistakes made when attempt is made to recall them. The chance connections of everyday life, such as thinking of a person in a place where he is frequently seen, and all rote learning, fall in the same class. Most learning is ability to recall in connection with something else. And this ability is due to association.

Suggested Limitations of the Laws of Association. — Many writers have questioned whether it is the mere occurring together that produces the connections or whether certain other conditions must be fulfilled as well. Three main conditions have been mentioned as needed in addition to the mere simultaneous or successive presentation of stimuli or events. Thorndike has asserted on the basis of experiments that formation of these associations is like forming habits, in that only those events are associated whose presentation is followed by an intense feeling. The intense feeling was induced by giving some reward after repetition of the two words to be associated. In most cases the pleasure was the satisfaction of knowing that the test repetitions were correct. He found that if in one series the subjects were told that their responses were right or wrong, and in another case nothing was said of success or failure, they learned much more quickly in the former çase. Extraneous rewards for success also hasten the learning process. Thorndike argues from this that there must always be some feeling following the presentation of successive stimuli if there is to be learning. Frequently in daily life one does not observe the feeling, but it must have been present. If not noticed the emotion must have been in a form so frequently present that it is taken for granted.

Intention and Association. — It has also been suggested that there must be an intention to learn if associations are to be formed. Thorndike and others compared the amount of retention, when words or numbers are merely being copied with no desire to retain, with copying after the workers have been asked to remember what they have copied. It is found that very many repetitions without intention to remember show little evidence of retention, while relatively few with the intention of recalling give a considerable number of successes. Once a foreign student in a Swiss psychological laboratory was asked to take part in a memory experiment. He did not understand what was wanted of him and so while he repeated the syllables as they were exposed did nothing more. When he came to the tests he knew nothing of what had been shown him. Then he was made to understand what was wanted. After that he learned as fast as the others. Daily observation shows the same tendency to remember what one tries to remember or at least not to remember what one makes no effort to fix.

Association and the Whole. — Another restriction to the law of association has been suggested by the Gestalt school. Members of this school insist that seeing elements together does not connect them; that we recall together only events or ideas that are parts of natural wholes. The general theory of the Gestalt school is that the whole is the unit rather than any sensation or other element. Only as events fall into these natural wholes is there any tendency to revive them, and then only when the particular whole of which they are part is dominating the individual at the moment. They regard the intention to recall as one phase of the whole. They also say that we recall things better if they have meaning, and that having meaning is an indication that the event belongs to a wider whole. The theory makes a general objection to believing that connections are formed between elements of any kind. The members of the Gestalt school even doubt that elements have any existence apart from the wider wholes which are the real units. We can accept their doctrine that elements are convenient hypothetical existences whose only value is that they are useful. But on the same line of argument, wholes also are hypotheses and are to be justified only in so far as they are useful. We shall go into this objection more fully in Chapter XIII.

The Nervous Basis of Association. — The real explanation of association must be found in the formation of connections in the nervous system. The connections formed in the association process must be different in one respect from those developed when a habit is formed. In habit or other motor learning the impulse spreads directly from the sensory to the motor neurone and thence to the muscle. Learning may be regarded as a mere development of a connection between neurones by frequent passing of the impulse. When an association is formed the sensory areas which are connected are in different areas of the cortex. They are also not on the direct line of sensori-motor connection. Thus when a child sees an object and hears the name of the object spoken, the object is seen in the occipital, and the sound is heard in the temporal lobe. There is also no common motor path of discharge. Sight of the object may evoke a movement to touch the object, the sound produces a turning of the head to listen. Nevertheless, after frequent repetitions the one sensory stimulus tends to evoke the other. When the child hears the word he recalls an image of the object. The fact to be explained is that a connection should develop between any two parts of the cortex which are active at the same time and that this connection should tend to persist.

The Conditioned Reflex. — The problem is the same as the explanation of what Pawlow has called the conditioned reflex. The conditioned reflex too was seen to be a transfer of a response that is originally connected with one stimulus to another stimulus which is given at the same time or a little before the first. Thus Pawlow proved that the salivary reflex could be transferred from the normal stimulus, the taste of meat, by giving the sound just before the meat was shown or put in the mouth. The normal reflex to meat juice in the mouth is secretion of saliva; the normal reflex to a bell is raising the ears. If the bell be sounded repeatedly just before the meat is put in the mouth or up to as much as twenty seconds before the meat is given, sounding the bell causes the flow of saliva. The Behaviorists have suggested that a child is induced to show fear of a cat by a similar conditioning. If the child is afraid of a loud bell and not afraid of cats, frequently bringing the cat near as the bell is sounded will transfer the fear response to the cat.

The Cortical Theory of Conditioning and Association. — Both conditioning and association are due to neural changes in the cortex. Conditioned reflexes, according to Pawlow, are not formed in dogs whose cerebrums have been removed. Essentially the learning in both instances must be due to the spread of connections from a group of neurones that is active in some one part of the cortex to another that is active in any other part of the cortex. As has been seen in connection with motor learning, there is always an irradiation of nervous impulses from an excited area. Why this irradiation in the case of a sensory stimulation should extend to another excited area offers a second problem. Kappers and Child have both shown, as was stated in Chapter III, that when neurones are developing in the embryonic stage they grow towards centers of excitation or activity. If we regard this spread of impulses as an analogous case, it may well be that there is still in the adult an extension of processes towards neurones that are active. The axones themselves are of course not capable of growth in the adult stage, but different theories have suggested that the dendrites and end-brushes may extend under stimulation. On Sherrington's assumption that the changes in the synapse is some decrease in the resistance of the membrane, the impulses may merely spread across membranes that are already in contact.

On either picture we must assume that there is a spread of impulses from one region of the cortex which is active to others that are also active. This spread of impulses, as Adams has insisted, must go in both directions; there must be a spread along different groups of neurones from each active region to the other. As a result of this two directional spread, the excitation later of either of the areas will tend to arouse the other. In our illustration, the sound of the word arises when the object is first seen, then the object when seen again tends to recall the word. The more frequently the two are repeated together, and the more interest or emotion is aroused by the experience, the more likely is one to recall the other. On the neurological side, formation of an association or of a conditioned reflex consists in this spread of nerve impulses from one to the other of the excited areas in the cortex. This common activity and the resulting connection make the excitation of either area likely to revive the activity of the other.

Classification of Association on the Nervous Side. — The different forms of the older classification of associations may be referred to these neurological theories. Simultaneity, and less directly succession, may be regarded as instances of the spread of impulses from one active area to another. The spread of the nerve impulse from one area to another opens synapses and so establishes paths between the two active regions. This is the nervous correlate of association by contiguity. Association by succession has approximately the same explanation. The stimulus applied second in the series excites the neurones of the area corresponding to it so soon after the first stimulus has excited its area that the two excitations overlap in time. The activity of the second begins before the first has ceased to act. Stimulation spreads from the area first excited to the second and in less degree from the second area to the first just as it does when the two stimuli are simultaneous.

Association by similarity requires for its nervous explanation that we regard the two similar objects as made up of elements that are in part identical, in part different. What one calls an idea is always complex and may be pictured as corresponding to the action of a number of neurones. In what is classified as association by similarity, a mass of neurones corresponding to the first idea are active, and as time goes on, parts of the group cease to be active. Only the one group that corresponds to the part of the idea most attended to at the moment persists in its activity; and from this, new neurones that correspond to the elements of the second idea are excited by virtue of their previous connections with the persisting portions of the first. On the side of consciousness, many 'ideas' in the popular use of the term are complexes of experiences, complexes of sensations; probably also the action of many different neurones is involved in their appearance. In the recall of any complex idea, these different elements probably enter into many different combinations, and the effective connections are between the elements, not between the larger masses. Thus when an idea recalls another similar one, the similarity is due to some common element, and this common element may be regarded as persisting from one idea to the other. In one idea, everything disappears except the elements that are common; these persist and gather about them by association the other elements which with them may be regarded as constituting the new idea. When the ideas are classified afterwards, they are seen to be similar, the association is said to be by similarity, but the effective forces were the waning of certain elements of the first idea and the excitation of others by those remaining. Association by similarity is really through partial identity, and the identical element furnishes the bond of connection.

Such an explanation would be anathema to a follower of the Gestalt school. He insists that ideas exist as wholes and are incapable of being resolved into elements. He emphasizes similarly the reactions of interrelated groups of cortical areas. This asserts merely that cortical action and ideas are both by units. No further analysis is attempted and the explanation is correspondingly vague. It is in consequence difficult either to prove or disprove. They do not admit associations and so have nothing to explain.

The Limits of Association. — Not only must we limit the application of the doctrine of association by the assertion that it is the neurones at the basis of the elements of ideas that are associated rather than the ideas themselves, but we must also recognize that associations give only the possibility of recall, and that selection from the possible associates must be made by more remote factors. Most neurones or sensory elements have been connected at different times with several other elements, and may be regarded as having a tendency, whenever any one is aroused in any way, to rearouse each of the others with which it has been connected. Which of the possible elements shall be aroused is determined by the same elements that control attention. A discussion of these may be postponed to the next chapter. For the present we may say that the return of an experience or the renewal of an excitation of a group of neurones depends in some degree upon the continued activity (perseveration) of the elements in question, an activity that lasts for a relatively short time, but for the most part depends upon the fact that, when any two groups of nerve cells have been active together at any time and one is reëxcited, that excitation tends to rearouse its earlier associates.

IMAGE AND SENSATION. CENTRALLY AND PERIPHERALLY AROUSED SENSATIONS

The remembered and imagined experiences of an individual may be studied not merely to learn how they are retained and how they are revived, but also to determine what they are like and how they differ in quality from sensations directly aroused by an object. This is the structural side of the problem of memory as opposed to its functional aspect. With this purpose uppermost, we may study the content of remembering or imagining just as we studied the qualities derived from external sensations. One can determine the qualities that they exhibit. This is most readily accomplished and the results most clearly stated if one compares their characteristics with the characteristics of sensations.

The problem is complicated by the fact that most untrained observers do not notice the imagery that is present when they recall an event. They are content to know that they recall an object and can describe it. In the terminology at the beginning of the chapter, they are concerned only with the function of recall, not at all with the structural elements involved. Several trained observers assert that that they do not have images; they have no definite mental content when they recall an object but have merely the certainty that they have seen it before. Our present problem is to determine what is in mind for the individuals who have images when the object is recalled. If one is attempting to recall a desert or a mountain landscape seen years ago, for example, one may repeat words that have been associated with the experience without any definite picture of the landscape, one may have fleeting bits of yellow sand or snow-covered peaks with many vacant areas or dark gray regions with no definite pictures, or one may have a clear and distinct picture from which one may paint or describe many if not all of the details. Our question at present is how these images differ from individual to individual, and how they resemble, and how they differ from, actual sensations.

Images Compared with Sensations. — Two methods of investigation have been applied to the solution of this problem. The first of these was used by Külpe[1] in an experiment to determine how one might distinguish faint sensations from imagined or remembered experiences. Faint sensations were chosen because memories are generally believed to be fainter than sensations. Investigators were placed in a dark room where faint lights of different colors could be thrown upon the wall. At a given signal, the observers were asked to say whether a light was seen and then, if it were seen, to say whether it was objective or merely imagined. At times a light was really shown, at others not. In most cases at the signal the observers either saw or imagined a color. After the report had been given, an attempt was made to determine what differences were used as a basis of deciding whether the image was really seen or only imagined. In this, observers differed. All agreed that there was a constant difference in quality. The imagined colors were more transparent, were net-like or clouded. The sensations seemed brighter, they entered and left consciousness suddenly and as wholes, had a more definite form, were clearer, and were given a more definite position in space. They were distinguished also by the more active tests, — that sensory colors left an after-image, were stationary when the eyes moved and vanished on closing the eyes, — while the reverse held in each particular for the imagined processes. In addition there were individual peculiarities from man to man; for example, greater duration was given by one as characteristic of sensation and by another as characteristic of the image. The results of this investigation indicate that characteristically different qualities attach to the processes aroused through association which distinguish them from the real sensations.

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[1] Külpe, *Philosophische Studien*, vol. 19, pp. 508–556.

The Projection of the Memory Image. — Another investigation gives approximately the same results by a method even more striking. Miss Martin[1] found that it was possible after a little practice to project a memory image outward into space, where it might more readily be compared with sensations. The different location of images and sensations serves in our ordinary experience as one criterion for distinguishing them. We refer perceptions to the point where the object is assumed to be in the outside world, while the memory or imagination either is given an indefinite place, is projected backward within the head, or possibly referred to the place where it actually is. Usually it is not seen upon the surface that is actually presented to the eyes. Miss Martin's observers found it possible to bring the image and the object side by side. When the difference in projection that ordinarily exists between images and perceptions had thus been removed, it was found that there were still characteristic differences between the two in their coloring, in definiteness of contours, in clearness, intensity, and stability. The sensations had the advantage in each of these respects. One other characteristic is the relation to the movements of the eyes. While in these experiments the images did not always move with the eyes, there was always a tendency to movement when the eyes moved that could be avoided only by considerable strain. All of these criteria for distinguishing between the two agree with those indicated by Külpe's investigation. One other presents itself for certain observers, — that is, the tendency to see the images in front of the background of sensory objects which may be present. The background may be seen through them as through a veil. In general it is noticed that sensory impressions interfere with the perception of other objects behind them, while images offer no obstacle to perception.

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[1] Martin, *Die Projektionsmethode und die Lokalisation visueller und anderer Vorstellungsbilder.*

These results afford concrete evidence for believing that individuals who have definite images also have means of distinguishing them from sensations. Images that correspond to no immediate sensory stimulus but are aroused through association processes are sufficiently different from the sensory experiences to prevent one from being mistaken for another. It is true that one seldom notices these characteristic differences unless they are called to one's attention. That careful observers working under experimental conditions do detect them makes it likely that they exist more generally and that they serve as the criteria by which one process is ascribed to the world of memory and imagination if it has one group of qualities and to the world of external things if it has other qualities. That the criteria are ordinarily not noticed is to be explained from the fact that in our ordinary life we are more interested in deciding where objects belong than in detecting the differences on which that decision is based.

In addition to these differences in the mental content, the connections in which the experiences present themselves also play a part in determining whether an experience is objective or subjective. If the object or event follows naturally upon other events that are recognized as objective, it is regarded as a sensation. If, *e.g.*, the sound of steps is heard outside, the bell rings, a servant answers, and a moment later a friend enters the room, there is no question of the objectivity of the experience. If, on the other hand, a letter in a familiar handwriting is seen and then an image of the friend who wrote the letter appears, there is no doubt that the image is subjective. One event fits into the world of things, the other into the world of memories, and in consequence the one is accepted as real, the other is referred to the past. This placing of the mental process in terms of antecedent events and the setting is undoubtedly the most important of the factors that lead us to discriminate between the objective and the subjective. Again this operation is not noticed for itself. One knows at once that one sees an object in the one case and that one merely remembers it in the other. The method of remembering is no more noticed than is the method of perceiving. That it is necessary to make the distinction is seen from the fact that in hallucinations and in dreams mistakes are made. The processes aroused by association alone are referred to the real world and are treated as objects.

VARIETIES OF MENTAL IMAGERY

The content that an individual has when he recalls an event is not only different from the content of the original perception, but it is also not constant from individual to individual. All the people in a group may think of the same thing but probably no two will have the same image when the same thing is represented. We can best indicate these differences if we classify them with reference to the sense departments that are used predominantly by different individuals. Charcot first noticed that the impairment of efficiency with a given brain injury varied greatly with the habits of thinking that the patient had been accustomed to in his earlier life. If the visual area were disturbed in one man it might entirely incapacitate him, while that area might be injured in another with no noticeable impairment of his efficiency. This suggested that there might be marked differences in the sense materials used by different individuals.

Galton,[1] acting on the suggestion, made a careful study of the way different individuals recalled and imagined events. He made a careful examination of the way a number of individuals recalled the breakfast table, with the result that some were found who could merely recall the way the dishes and the people at the table looked, others could remember the sounds of words and the rattle of the utensils, still others could remember only how their own various movements felt as they were made. More rare were the individuals who could remember the odors and tastes of the food, and these memories were usually indistinct and subordinate. Galton also distinguished the verbal type, individuals who recalled everything in words, either as words seen, or words heard, or words as they would be felt in the vocal organs at the time they were uttered. In older individuals, particularly men of science and others who indulged much in abstract thought, the verbal tended to predominate over the more concrete imagery.

Galton or certain of his expositors give the impression that an individual is likely to have one type to the exclusion or at the expense of all others. Certain of the later writers have still more exaggerated this assertion of the mutual exclusiveness of types. Stricker, for instance, has argued that every one must be of the motor type, and further that the recall consists in nothing more than the reinstatement, in some slight degree, of the movements made on a large scale at the time of the original experience. He challenges any one to think the sound of *o* with closed lips, and regards failure to do so as proof of his contention that all thinking is in terms of a reinstatement of some movement. Most recent investigators, however, incline to the view that, while imagery is much more restricted than sensation, most individuals have memories from more than one sense, many from two or more in approximately the same degree. These latter individuals will use the type of imagery best suited to the problem in hand. If, for example, one both paints and composes music, one would plan a picture in visual images and compose in musical tones. While one or more types may be lacking in most individuals, and one or more be preferred, the sharp classification into visual, auditory, etc., seems too rigid to harmonize with the facts.

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[1] Galton, *Inquiries into Human Faculty.*

Concrete Imagery. — It is customary and convenient to distinguish two general types of imagery. The one reproduces the event as nearly as possible in the way it was originally experienced and uses the same sense materials that were present at the time of the event. This is the concrete type of imagery. Since, however, man describes almost every event in language spoken or written, many men have developed the tendency to use the speech equivalents in place of the original images. Individuals use the three major senses, sight, hearing, and kinæsthetic, in varying degrees in the recall of events. Less used, because less important for ordinary events, are the olfactory, gustatory, and cutaneous sensations except as cutaneous combine with kinæsthetic in the touch activities. Some have denied that smell and taste impressions can be definitely recalled. Recently discussions have turned upon the question whether individuals use one type of imagery alone, or show a combination of two or more of the major senses, and which of these sense departments is more frequently utilized.

Professor Griffitts has made one of the most recent studies of these problems. In a study of the imagery of more than a hundred students, it was found that more than 90 per cent relied mainly upon vision. Next comes auditory imagery, and kinæsthetic is last. The distribution is about the same whether the more subjective method was used of asking the student to say how he recalled a specific event or a more objective one of asking the student to perform some task and inferring his imagery from his relative success with different tasks. No one was found who was entirely lacking in visual imagery, although one had the merest trace. It is important to emphasize that there is no sharp division into classes or types, but that the degree of imagery shows gradual variations from a mean. It is interesting, too, to note that if an individual uses revived material from one sense more than from any other, it does not mean that he stands high in that form of imagery in comparison with other members of the group. For some of Professor Griffitts' students visual imagery was dominant, but was less clear and less effective than the visual imagery of others who used auditory imagery most frequently. These results were obtained on students and probably hold only for that age. Galton found with his subjects that there was a tendency for concrete imagery to become less vivid with advancing age.

Verbal Imagery. — The recall of words or preparation for active speech may also be possible through the different sense departments of hearing, kinæsthesis, and sight. The words may be formulated as one would feel them as the vocal organs move, or as one hears them, or as one sees them on the printed page. Griffitts found in his studies that students were more likely to think of words in what is known as inner speech, that is, one would present them to one's self as words heard or as they are felt in the vocal organs. These two together were dominant in 76 per cent of the students. The others used the visual-verbal imagery. Auditory imagery is more prominent than the kinæsthetic when inner speech is divided into these two components. In that series of tests, the proportions were visual 49; auditory, 31, and kinæsthetic, 16, per cent. The dominance of inner speech over the visual verbal is to be ascribed to the fact that the child learns to talk before he can read and continues to prefer his original way of representing words to himself. The kinæsthetic impressions may, in some individuals and at times in all, be increased in intensity to take the form of actual movements of the vocal organs, as Stricker suggested. Watson and his school have argued again that all thinking is nothing more than this sub-vocal movement of speech organs.

The Origin of Imagery Types. — The differences are probably due in part to heredity and in part to training. Evidence may be adduced by a few cases in favor of a hereditary predisposition. Dodge, who is almost altogether without auditory imagery, reports that his parents had the same lack. The inheritance of musical ability, which in all probability depends upon the possession of auditory imagery, may also be cited as evidence of a hereditary tendency. On the other side, training has been shown in several individual cases to have exerted an influence in changing the memory type. Particularly with school children, it is found that they can be trained to considerable facility in types of imagination in which they possess no natural skill. Even in adults long practice gives results in the development of new forms of imagery. A student who cannot spell because he cannot see the words in his mind's eye can by repeated effort bring himself to visualize the words, and to make some degree of improvement on the practical side. It seems, then, that heredity and training coöperate in determining imagery. Certainly training modifies the hereditary character. It does not follow, however, that spelling is absolutely dependent upon the possession of the visual type. One may spell by reproducing in order the auditory or the kinæsthetic equivalents of the letters. In general it seems that there is no close correspondence with what one would expect in the imagery actually used for different functions. Players of chess blindfolded very generally use symbols or words for reproducing the position of pieces on the board instead of visual pictures as *a priori* would seem more effective.

Synæsthesia. — A curious occasional phenomenon is the close connection in certain individuals between objects or sensations of different senses. Numerous cases have been recorded of individuals for whom letters or words have colors which are essential to them: *a* may be pink, *o* green, etc. The words either have a color of their own, or take on the color of the letters that make them up. Several cases have been reported, too, in which musicians have colors aroused by certain tones or tone combinations, and these may seem to be essential components of the tone effects. Thus Myers reports that Scriabin, the Russian composer, had a different color for the different keys. The major keys of C, D, B, and F# have the colors of red, orange-yellow, blue, and violet, respectively, and the effects are so strong that he desired to have his compositions rendered to the accompaniment of colored lights that should flood the hall from concealed lamps. In another striking case odors were associated with colors; in fact, were often only perceived through their color associations.

Two theories have been held to account for the phenomenon. One asserts that the connections have been made through association. The other argues that the connections are fundamental. Perhaps they are due to the fact that there is some common feeling or other element which serves to connect the two sensory components. The second theory, if true, must admit that individuals who possess this idiosyncrasy seldom agree as to the colors that shall be associated with a particular tone, although each person feels that the connection is universal and necessary. The association theory is as yet equally unproven, although a few characteristic peculiarities suggest that the connection of colors with letters or tones may be due to old habits. Thus in three sisters whom the writer investigated, one of the few correspondences was that *j* was said to have a grayey brown color to all three, an obvious connection with jug. How far heredity enters as a determinant, how far fundamental common characteristics between the sensations connected are important, and how far early associations must be the explanation, is still largely a matter of conjecture.

In brief, the qualities of memory and imagination are the same as the qualities of sensations. They are a little less numerous, they do not show quite the same distinctness, but memory and imagination add new qualities to sensation. These impressions are recalled through laws of association not so very different from the laws of habit, and are woven together in new patterns to give features of remembered events that suit the purpose of the moment, or to make new constructions of imagination or reason.

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CHAPTER XII

SELECTION OR ATTENTION

A CHARACTERISTIC of all reaction and of all awareness of objects is the selectivity of response. Only one stimulus may be responded to at a time. Only one object or idea may be appreciated fully at the same time. This fact of selection is given the name attention popularly and the word is also applied in psychology. Recently a tendency has developed to avoid the use of this and other terms like memory, emotion, etc. for some fear that it may seem to imply a special force or faculty in the individual which causes or performs the function. No such thing is intended here. There can be no objection to the use of these special words, provided it is made clear that the word is used for convenience to describe a related group of facts or functions and that there is no single thing or force which is assumed to perform all the functions. However it may be designated, there is no question that the various forms of selection are highly important in determining many phases of our mental life.

The Phenomena of Selection. The consciousness of the individual is undergoing constant change. The same idea does not persist for many seconds and its constituent parts do not remain unchanged for more than a fraction of a second. These shifts are from one stimulus in the physical world to another, from outside stimulus to memory process, interrupted by awareness of questions and problems that are to be observed now. Record for a minute the objects and ideas that you become aware of and you will obtain concrete evidence of the kaleidoscopic character of the conscious processes. Similarly watch an animal, a child, or an adult in a period of relaxation and you will see a constant play of the sense organs as first one stimulus then another attracts him. Some cause but a momentary shift of the glance, a turning of the head to the source of a sound or the change in respiration that indicates an appreciation of an odor. Others are more prolonged and cause a shift of position for a more complete investigation, with preliminary adaptation of the muscles for some response. Whether considered from within or from without, these evidences of selection are found everywhere and selection itself is a controlling influence in almost all mental and physical responses. To list the forms that this selection takes and to discover the conditions under which it takes place is one of the important problems of psychology.

Forms of Selection. — Attention may be regarded either as a term to designate mere selection or be made to include the fact that at any moment mental processes differ in clearness. In the first case one assumes that a mental process either is or is not dominant. That these changes in dominance are constantly occurring is evident to any one who watches himself for a moment. First the book you are reading, then the noise of the plane overhead, then the discomfort from your position, then a thought of the bill that comes due tomorrow, takes the primary position. This is the crude process of selection.

The Degrees of Clearness. — Consciousness is not quite so simple as this all-or-nothing description implies. You are aware not merely of the one thing that is most prominent, but you are also aware in slighter degree of the field in which it is seen and of the object that is to dominate later or the one that did prevail a moment ago. Wundt likened the field of consciousness to the field of vision. There is always a central or clearest point, and about it the components fade off to a zero of effectiveness. The point of maximum attention corresponds to the fovea in the field of vision, the other regions of consciousness to the periphery. Attention may wander over the field of consciousness in much the same way that the eye wanders over the field of vision. The characteristic common to foveal vision and attention is the increased clearness that comes in both cases. As a result, contours and differences in intensity between parts are better discriminated. Temporal effects of attending to a sensation have been noted in hastening its entrance and in keeping it a little longer in consciousness. All these differences would increase the importance of the impression attended to as compared with one that is not attended to.

Does Attention Increase the Intensity of Sensation? — What change does attention bring about in the content of consciousness? The answer is to be found in the observation of one's own state as one attends, rather than in a verbal description. Certain it is that the object or event attended to becomes in every way more important for consciousness; it stands out above the others at the moment, is also more likely to be remembered and to start new trains of thought. The character of the change can be given only by comparing it with other known changes and indicating the similarities and differences between them. In many respects it is like an increase in intensity. Increase in the intensity of a physical stimulus also make it more likely to affect consciousness, increases the probability that it will be remembered, and quickens the reaction to it. That attention and increase in intensity are not identical is evident from the fact that we never mistake one for the other. We never assume that a sound has actually become louder when we have only turned attention to it. On the other hand, it is certain that the two changes have much the same practical effects; both attention and intensity make the experience more important for consciousness. Attention also produces an increased clearness of outline. In this respect it has an effect similar to that due to increased closeness of the nerve terminations.

Figure and Ground. — A recent new way of emphasizing the phenomena of selection has been introduced by the Gestaltists

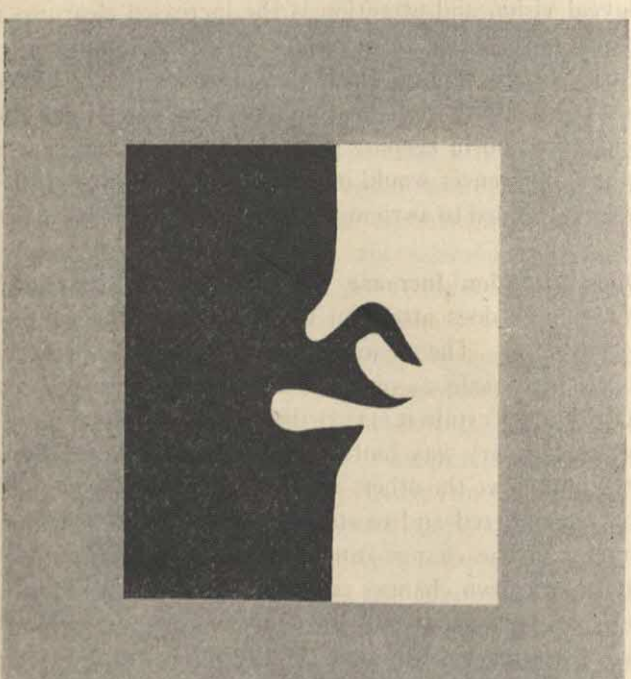

FIG. 86. — Illustrates alteration from figure to ground. (From Rubin.)

by adopting the terms *figure* and *ground* from Rubin to describe the tendency for one phase of a figure to dominate over other phases or interpretations. Usually the dominance of a separate part of a field is immediate and that is regarded as the thing of the moment. The more monotonous field about is the background against which it is seen. Many optical figures, however, may be seen under two aspects. One part or the other can be made the prominent aspect, the other shrinks back and is important only as the border of the other. In the figure (Fig. 86) either the curved black figure can be made prominent and seem to be an open-mouthed schematic bird, or the white can be made the figure and be seen as a man's tongue protruding into the black ground. Rubin asserts that figure is different from ground not merely in the fact of dominance, but in the seeming protrusion of the figure a little above the surface. There is a slight change in color too as the figure becomes the ground. When it is regarded as a figure, it has solid surface colors, while when it becomes the ground the colors seem to be drawn over the surface like a veil, are what is known technically as film colors.

The Levels of Clearness and Selection. — The notion of figure and ground would seem to imply that at any moment there are only two degrees of definiteness or clearness — the dominant phase and the background. The interpretation of the phenomena as degrees of clearness would permit various grades of dominance, or clearness. Much discussion has developed on the point at different times. It seems fairly certain that observation at any moment shows more than these two degrees of dominance. In the figure and ground experiment one is aware not merely of the figure and the immediate background, but also of still wider surroundings. One can probably recognize various grades of distinctness in the parts grouped as the background. At the same time in recall and for many practical purposes, one thinks mainly of the figure, and the ground is much less considered, in some cases not appreciated at all. When one phase is seen as the figure, the object as a whole may not be recognized as that which was seen before when the present ground stood out as the figure.

Attention as Function. — The functions which are designated as increasing the clearness of a phase of an experience, selection, and the more recently considered change from figure to ground are all closely connected. It is convenient to apply the term *attention* to them, provided we emphasize the warning that we mean only a convenient grouping of functions about a common aspect and not a separate force. Grouping them we may find common characteristics in the empirical features and also common accompaniments of a mental sort. The selection affects not merely the change from one stimulus to another, but also change from stimulus or sensation to the central processes of memory or imagination. When one is reading or observing any object, older events and anticipations of events from the future break in from time to time. How and why these changes from figure to ground, or from emphasizing one part or phase of an object to another occur is obviously an important problem. It is our task to study the accompaniments and conditions of these changes. We shall also see that one important series of conditions in the control of memories and ideas exhibits many of the same laws as these objective changes. The two may be regarded as expressing the same principles.

MOTOR PHENOMENA OF ATTENTION

Movement and Attention. — The most important changes that take place during the shift in emphasis of conscious processes are muscular contractions. These reveal themselves to the observer in various ways. To the man who is watching they indicate to what he is attending. For the observer himself the strain sensations that come back from the contracting muscles are interpreted in various ways. Very frequently he is not aware of what they are or what their function is, but gives them various interpretations. These movements include those necessary to the adjustment of the different sense organs and contractions of muscles at different degrees of remoteness from the organ involved.

The Adaptation of the Eye. — Three different changes are made by the eyes in attending. First the eyes are turned so that the object that has caught the attention shall fall upon the fovea in both eyes. This gives the best image. Turning both eyes upon the same point also insures that the image from the object shall fall upon points which combine to give a single image, and so that object shall be seen as one. The ciliary muscle about the lens also contracts or relaxes to adjust the shape of the lens to give the clearest possible image of the object. Each of these movements is made automatically as a result of the general processes that control attending. All the contractions take place together. Accommodation and convergence seem to be connected from a very early period so that one does not occur without the other. If one attends to a distant object, the external recti muscles contract, the internal recti relax. At the same time, the ciliary muscle relaxes, the ciliary ligaments become taut and make the lens flat, so that a clear image of the distant object is obtained. The only way these muscles may be contracted is by fixing attention upon an object at the appropriate distance.

Adjustment in Audition and Other Senses. — In the other senses, the adjustments of the sense organs are less striking, although still present. The head is turned toward the source of sound to increase the certainty of receiving the tones. This is particularly noticeable if one ear be defective. The head will then be turned to one side when listening, to receive as much as possible of what is being said. The muscles in the middle ear probably have a protective function only, and play little part in attentive listening. When one is asked if one notices smoke, sniffing follows automatically to bring as much air as possible to and through the nostrils. Similarly, when a cook passes critical judgment upon a product of his art, the substance is pressed more closely against the tongue by bringing the tongue against the roof of the mouth. In feeling a surface the hands are kept in motion, in order that the slighter irregularities may be noticed. In the blind this frequently develops into a series of slight movements of the finger tips made automatically and almost unconsciously. Comparing weights calls out similar lifting movements of the whole arm. Each sense, then, has a series of accommodatory movements that make the sensation more adequate and complete, movements that come without thought, are an immediate outcome of attending, of the desire to know more about the object in which one is interested.

Mimetic Movements. — Another characteristic group of movements is carried out by the voluntary muscles of all parts of the body, which depend for their character upon the nature of the thing attended to. Every movement that is absorbing attention or that is watched attentively tends to induce or be accompanied by similar movements on the part of the onlooker. Thus if one is watching an athletic contest closely, it is probable that one will make slight movements in imitation of the contestants. This tendency to act out ideas explains many of the cases of mind reading and similar processes which approach the occult. Slight movements, made without the knowledge or intention of the one and interpreted without knowing how by the other, serve as a basis for the communication. The capacity for interpreting these slight unconscious movements is found in animals as well as in man. The feats of *Kluge Hans* and the Elberfeld horses, which seemed to do sums and perform other wonders, were found on closer examination to depend in part upon noticing signals from the trainers which were given without the knowledge of the observers. Thus a horse, when given a sum on the board, was trained to stamp as many times as the number required in the answer. It was found that he really solved the problem by continuing to stamp until the trainer indicated his satisfaction by some slight movement. These movements of the muscles of the face and of the bodily attitude constitute a large element in the appreciation of the mental attitude of a companion.

Diffuse Motor Discharges. — Still another large group of movements of the voluntary muscles accompanying attention is constituted by a contraction of most of the muscles of the body, due to a general discharge of impulses, a sort of overflow of motor excitations. As one attends strongly to any object one becomes tense, the brow wrinkles, the teeth are set, the fists may be clenched. The degree of tension increases with the degree of attention. One uses the feelings of strain subjectively as a measure of the amount of attention, and one also regards the amount of contraction as a measure of the attention of another. It is not necessarily true that the efficiency of attention is measured accurately by the amount of contraction or of the resultant feeling of strain. These strains seem to be more pronounced when the resistance to be overcome is great, rather than when one is attending to the best advantage. But it is taken by the individual himself as an indication of the effort that he is exerting in attention, or of the effort that he is exerting in any field. Closely connected with these general contractions and accompanying marked attention is the inhibition of all movements. Some individuals must stop any movement they may be engaged in when they begin to attend, and in all there is a checking of movements when attention becomes close. It can be noticed most clearly in an audience. When inattentive, there is always a sound made by the rustle of garments, by other movements, each in itself too slight to make a noticeable noise, but which in the sum produce a marked disturbance. As soon as the audience becomes attentive, all this stops and silence ensues. These inhibitions are of value in listening for faint sounds; and in many other sorts of attention they may increase the effectiveness of the sense in some degree. While necessary for audition, they have become an accompaniment of all attending.

Changes in Circulation and Respiration. — Changes in non-voluntary physiological processes also are present. These are perhaps most strikingly seen in the checking of respiration. As one attends, the breathing is stopped. In a short period of profound attention the breath will be held and a sigh or deep inspiration will follow relaxation. In longer periods the breathing first becomes quick and shallow; in still longer periods it is slower, but also more shallow than usual. Similarly, there are changes in the circulation. The heart beats more quickly, the blood vessels contract in the periphery and expand in the brain, the blood pressure rises, the pupils are dilated, tears are secreted which give the bright eye of interest. Each of these movements renders the organism more efficient. Holding the breath removes the noises of respiration that might interfere with faint sounds. The quicker heart beat and increased circulation in the brain prepare for appreciation of the conditions, and for the activity that may follow. Attention, then, is a physical as well as a mental process. Accompanying increased appreciation of some one sensation or stimulus is a widespread irradiation of impulses to the muscles. These serve to increase bodily capacity, are an indication to an onlooker of attending and of the direction of attention. The sensations of strain which come from the contractions are assumed to measure the degree of attention. Most so-called mental tension is physical, due to these muscular contractions.

CONCRETE FACTS OF ATTENDING

The Range of Attending. — It is often asked how many things can be noticed at the same time. The question has been answered experimentally for vision by showing an individual different numbers of objects for less than a fifth of a second and asking him to state how many there are. The exposure used is too short to permit the eyes to move. Results agree that four or five objects may be seen at a single exposure. The number of objects that can be seen is relatively independent of the size or complexity of the object. A single dot or a group of three or more that makes a regular figure (Gestalt), a letter or a small word are all seen with approximately the same certainty. In fact a short word may be seen quite as readily as a single letter. It seems that what makes any object a single thing or Gestalt is that it has been used or attended to as a separate object or form. The number of auditory impressions is slightly greater than the visual, but they must of course be given in succession. Eight single ticks of a metronome may be appreciated when heard without rhythm, and when combined in a rhythm as many as forty — five groups of eight each — can be heard in a single unit. The experiments on vision also make it probable that the objects are not really seen all at once but that they are counted after the exposure in the immediate memory or memory after-image. Careful examination of the process of attending to objects exposed for an instant shows that the real study of the object is made after the exposure. Impressions persist in the memory after-image with considerable vividness for some two seconds, long enough to count the five objects successively. One really attends, then, to but a single object at a time, but five successive acts of attention can be completed before the vivid memory image disappears.

Much the same problem has been raised with reference to how many processes may be carried on at once. Occasionally one reads that some man is able to do two or more things at a time. Cæsar was said to dictate to several secretaries at once, and similar tales are told of others. Experiments made to test the point all indicate that more than one process may be carried on at one time, but only provided some of them are sufficiently automatic to require no attention. Thus it is possible to write from dictation and add mentally at the same time, and the time required for doing both will be less than the sum of the times for doing each separately. If one attempt to perform three simultaneously or to do two things, even one of which has not become pretty thoroughly automatic, more time is required to accomplish them together than separately. Here again it seems that one can attend to but one thing at a time, although it is possible to start one series of activities and let it go on of itself while one attends to something else for a time. Attention changes from one to the other just often enough to keep the different processes going.

The Duration of Attending. — A second empirical question concerns the greatest length of time that a sensation or thing can be held at a maximum of clearness. Related to it is the problem of the time that one phase or interpretation of a figure may be held dominant when a second phase is possible. This is the problem that the Gestalt school designates the problem of figure and ground. On the question of how long the same thing may be kept in the clear point of consciousness, the answer depends upon what is meant by the question. If one

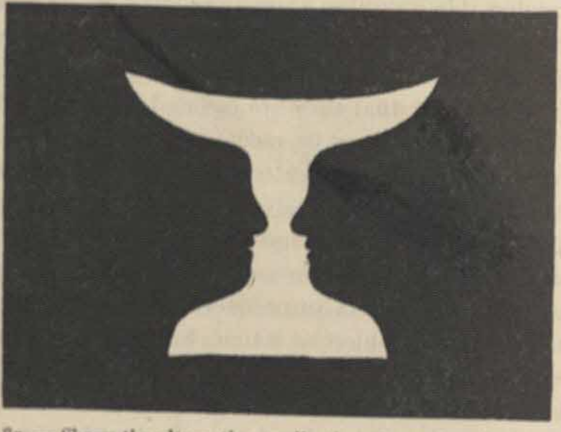

FIG. 87. — Shows the alternating application of two Gestalten. (After Rubin.)

makes the single thing large enough one may attend to the same thing indefinitely. One may read the same book for hours. If one measures how long a stimulus so faint that it can be barely sensed can be held definitely in awareness — it is found that it will be appreciated only for short periods; it ceases to be noticed in the intervals. Thus if one listen to the ticking of a watch or the faint tone of a telephone at a little distance, it will be observed that the sound will be heard for an instant and then will disappear, and these alternations will continue as long as one listens. Similar fluctuations are present during the observation of faint visual stimuli. The explanation of these fluctuations has been variously given as due to fatigue in the sense organs, either of the muscles or of the sensory endings, to fatigue of the sensory regions in the cortex, or to changes in the blood supply to the cortex, and even to fluctuations of mental energy. The explanation cannot be regarded as completely agreed upon, although considerable evidence has been given in favor of all but the last theory.

Complete Alterations of Content. — What is probably more truly a fluctuation of attention is seen if one will keep a record of the time that one can fix upon some single, simple object, a dot or a single tone. It will be seen that the single object will dominate consciousness for only a second at the most, then something in the neighborhood will crowd out the object, or a memory of some event of the past will intrude to exclude it. Between each of the other events, attention will go back to the dot. The observer will be sure that the dot has been present all the time, but it will not have been attended to. It seems that one can attend strictly and definitely for a very short time, a second or less. In addition there are waves of increased effectiveness which come and go every six to ten seconds. These probably depend upon fluctuating physiological processes, central or peripheral. If by attending to the same thing is meant attending to a general subject that contains changing elements, it is possible to attend for several hours — the length of time depending upon the nature of the material, the strength of the observer, and other conditions. If, however, we mean attention to one thing exclusively, one can attend for only a second or less.

Figure and Ground. — Of very similar character are the alternations between figure and ground mentioned above as described by Rubin under that name which have been emphasized by the Gestalt psychology. It has long been known that geometrical figures may be drawn without perspective and the perspective interpretation will change with the point of view and the expectation. Similarly if a red color be placed before the right eye and a green color before the left eye, the red will be seen for a time and then the green. There will be a continuing alternation from red to green and back. Rubin found that in the forms that were capable of a double interpretation as in Figure 87, there is the same tendency to alteration, once the two possible interpretations have been appreciated. In all of these cases the period that one figure will be held constant ranges from two to five seconds or more, according to character of the figure and the experience of the observer. The greater the familiarity with the problem, the more rapid the fluctuation. Rubin and other members of the Gestalt school do not regard the figure-ground alternation as connected with attention, but they are obviously closely related phenomena.

Attention and Distraction. — The problem of the effects of distraction upon capacity for work has been much discussed. The first experiments on the subject were made in an attempt to measure attention by determining how much external stimulation is necessary to prevent attending. The somewhat surprising result was to show that work was rather more likely to be improved than disadvantageously affected by distraction.

Even the clearness of a mental process has been reported as increased by distraction. Morgan tested the effects of loud noises upon the time required for solving problems. He found that when the noise first began, the time required for a solution rose, but soon fell below the time needed when there was no noise. Accompanying the increased efficiency was an increase in general motor tension. The key that gave the reaction was pressed harder and the circulation and respiration were disturbed. Ford repeated the experiments and confirmed them in general. Ford found in addition that after a period of noise, the quiet that followed served as a distraction. Work fell off at the beginning of the quiet period to increase again after a time as the worker adapted himself to the quiet. It seems that a distraction increases the general energy of response, physical as well as mental, and that the increased tension is more than sufficient to overcome the disadvantages of the environment. This extra output shows itself in an increased metabolism as Mrs. Donahue has shown, and in a following fatigue. In daily work one sees corresponding effects. Some students study by choice with the radio turned on, and assert that they can accomplish more than when all is quiet. The statement needs confirmation by experiment but it is possible that the noise serves to increase the energy output. It is probable, however, that the increased efficiency is at the expense of a greater fatigue. This reduces the advisability of the practice.

The Conditions of Attention

We have insisted throughout the discussion that the process of selection is an extremely important factor in determining the course of mental events. It is also important that it should be referred to definite causes. This is specially true because the popular mind is always inclined to seek for a single cause for any group of phenomena that have a single name. When we designate selection, the related increase in clearness of one mental phenomenon at the expense of others, and the acceptance of one phase of a picture as figure against another which serves as ground, as attention, there is always a tendency to make attention a causal force All that can be meant by the term is that these three processes have something in common with each other and that the popular thought has found it convenient to designate them all by the one word attention. For an explanation of the changes we we must look to various factors in the environment and in the immediate and remote past of the individual who sees or acts. The environmental factors are designated as the objective conditions, those from the past of the person himself as the subjective. It is insisted that these two groups of factors act directly upon the selection as a process and not on or through some factor or force independent of them. Attention is just the name we have given the fact of selection and the conditions under which selection occurs. We may repeat that it is not a thing or force.

Objective Conditions. — The characteristics of the stimulus that are likely to make the observer notice it may be said to constitute the objective conditions of attending. The intensity, size, and duration of a stimulus and its contrast with the surroundings determine whether or not it is likely to be attended to. Loud sounds, bright lights, strong odors force themselves upon consciousness, while less intense stimuli fail to attract notice. Contrast is important, as may be seen from the fact that a fairly bright light in the dark attracts as much attention as a brilliant light in full day light, or a light footstep in the silence of the night as much as the automobile horn in the midst of a dense street traffic. Less definite are the effects of extent and duration. Up to a very low limit likelihood of being noticed increases with increase in size or duration. Beyond this point little is gained with increase in size or duration, and at the extremes large objects tend to become merely the background and so are not appreciated for themselves. Long duration makes change impossible and so reduces the tendency to be noticed as is seen in the following paragraph.

Change an Important Determinant of Attending. — It is interesting to note in connection with objective factors that change is an essential element in arousing attention. One quickly becomes adapted to a continuous stimulus and ceases to notice it. A constant light is unnoticed, but the shadow cast by the passing of a cloud at once intrudes upon consciousness. The slight noise of the burning gas drops into the background, and as Fechner pointed out, the miller is oblivious to the sound of his mill, but the slightest change induced by a defect will be observed at once. The cessation of the stimulus in this case is as effective as an increase in the sound. A clock that has been ticking unnoticed in the study will be noticed when it stops and the last few ticks will be heard, — sounds that would have had no effect upon consciousness had they not ceased. The decrease in the size of an object moving directly away from us attracts attention almost as certainly as does the increase in size due to its approach. Each of these effects of objective stimuli might be explained as due to the universal characteristics of man or to the inherited capacities of his nervous system. But since they are universal to all nervous systems it seems simpler to regard them as of objective origin, than to assert that man's physical organism is adjusted through heredity to respond to stimuli possessing much energy and particularly to changes in the amount of energy affecting a sense organ.

Subjective Conditions. — More truly characteristic of the attention processes are the subjective conditions. We ordinarily think of attention as a free act by which we turn to one thing which at the moment it pleases us to notice, and exclude all others. But usually there is no conscious antecedent desire, and, where there is, the desire is due to the experience or heredity of the individual and these are to be regarded as the real conditions of his attending. Sometimes the individual knows that he desires to attend because of the antecedent experiences. More often he is merely aware of the entrance of a mental state and does not even wonder why. Careful observation and experiment on the preceding circumstances of different selective activities indicate that we may distinguish some five groups of subjective conditions.

I. Immediately Preceding Sensations. — One of the definitely demonstrable antecedents of selection is the immediately preceding sensation or idea. This can be best illustrated by hearing out overtones. If one is listening for an overtone in a note played on the piano, and has heard another note of the same pitch just before, he will distinguish it easily, while unless he has considerable training, he cannot hear the overtone without this aid. So if one desires to hear the first overtone of *c* on the piano, and will strike *c′* just before one strikes the *c*, one will notice the overtone, the *c′*, without difficulty. Again an object just seen in a particular place will strike the eye when one seeks for it, when previously it would not have been noticed. Very similar in its effect is a vivid memory image. If one can call up a definite image of what is to be seen, the corresponding object will be noticed. It is probable that the skill of the practiced observer in hearing overtones is due to the fact that he can recall accurately the tone that he is to hear. This definite image replaces the sensation in its effect of making the overtone likely to come into mind. Similarly, in a puzzle picture, to recall the concealed face in its actual place is a guarantee that the image will be recognized when one looks a second time. What shall be figure and what ground, in the terms of the Gestalt school, is also frequently dependent upon what is pictured before one looks at an outline. The image definitely recalled aids the entrance of the corresponding percept, in the same way as does the immediately preceding sensation.

II. Purpose or Mental Attitude. — Most important and striking of these subjective conditions is the influence of a factor that is variously designated the *intention*, the *purpose*, or the *question* dominant at the moment. When one has the intention of seeing a particular thing, that thing will come to consciousness. If some one suggests that you look for a cell in the field of a microscope, the probability that you will see it is thereby increased. In daily life this purpose is the determining factor in all observation. One usually sees or hears what one desires to see or hear, or what harmonizes with the intention. All that does not harmonize with that purpose, unless especially favored by objective conditions or other more general subjective conditions, might as well not have been offered to the senses. If one is interested in what an individual is saying, one will not notice his accent no matter how unusual; and if one is a phonetician and intent on the study of the peculiarities of speech, the meaning may be altogether lost. One does not notice the wall paper in a room unless the pattern is striking, or one is deciding on wall paper for one's self and so has that as a dominant purpose at the time. Some objects that have been under one's eyes for years may never have been noticed unless some purpose made it desirable. To use a familiar instance, the reader cannot say without looking whether the four on his watch is iv, 4, or iiii, in spite of the number of times it has been looked at. One looks to learn the time, not to see how the numerals are printed, and sees just what one looks for, and nothing else. This is typical of most observation. Man is blind to what does not correspond to his momentary purpose.

This purpose or mental attitude may be aroused, either from without or from within. From without it may be due to a question asked by another, or to some task that has been set, or problem that has been raised by one in authority. From within, the purpose usually arises by a suggestion from something that has been seen. Something external or internal starts a train of associations. That raises a question about an object present, and one looks to the object for an answer. The answer to the first question suggests another problem, and thus a train of associations in the series of questions leads to one observation after another. Observation is most frequently the result of a series of problems self-set for solution. When one has the problem or the question, finding the answer is relatively easy. Without the problem, observation is indiscriminate and relatively unprofitable. In this sense thought usually precedes observation, but the thought itself grows out of preceding observation, and so both are to be regarded as parts of a continuous progression in which each thought suggests attending to something. The results of each attending suggest a new question, and the series lasts until broken by the irruption of an intense stimulus or some necessary task of daily life. This in turn starts a new series of questions.

III. Education and Attention. — A number of more remote conditions also aid in preparing an individual to attend in a given way at any moment. First of these is the earlier training and previous experience. These work in two ways: in the first place, they increase capacity for observation of the object one desires to know about, and largely determine what one desires to see. The skill of experts in any sort of observation depends upon training. The skill of expert microscopists in any realm, of musical critics, of tea and wine tasters, and of the woodsman in tracking game and in seeing the signs of the forest, all comes from training. The expertness depends in part upon knowing what to look for, of having in mind the problems that are to be solved in a particular connection; in part, the skill in discrimination grows with practice, and is probably dependent upon a number of physiological factors. Training has also obvious effects in determining what sort of stimuli shall be selected for attention. This works in two ways. In the first place, it helps to raise questions and to organize purposes. One cannot have a purpose without some preliminary knowledge of the thing to be seen. What to look for in animal structures is known in any considerable degree only by individuals with some training in zoölogy. The trained machinist has a series of questions in mind as he begins to examine the engine that you have called him to repair, and with these problems which have grown out of his experience he looks with a definite series of purposes and easily discovers the source of trouble. But, secondly, even with no definitely conscious purpose, one sees the things that one has been accustomed to deal with, or that one has been trained to see. The printer without effort sees details of a book that escape the ordinary reader.

IV. Social Forces in Attention. — Still another important group of influences are the outgrowth of social instincts. These compel respect for the ideals that one takes from society, and make one strive to do and observe certain things because of the fact that others expect such behavior. The student attends to a lesson when fatigued or when the lesson is not interesting in itself because he desires to make a good record, to pass an examination. Or again, a man desires to make a good record for the sake of the approval it will win from persons he respects. Or selecting a more permanent aspect, one desires to obtain a satisfactory knowledge of a subject for the value it may have in later years, or in the profession that has been adopted. Again, however, choice of a profession depends largely upon the social favor that the profession has in the group with which one is acquainted. Even the belief that the particular subject will help in the profession is often taken from society. It is a preference for the remote as opposed to the immediate good, but the more remote is accepted as good and obtains impelling force because of the influence of society. Society approves each separate step, as well as the attainment of the end; its pressure is felt throughout the whole course of the attainment, and thus at once guides and compels towards that end. For our present purpose it may be regarded as the source of all attention from constraint, as the cause of all attention against one's momentary desire.

V. Heredity and Attention. — A final group of influences upon what is likely to be selected may be referred to the innate characteristics of an individual. Certain tendencies that are present in all of the members of a race may be ascribed to a common descent. Less assured are characteristics of each family which seem to appear in generation after generation If these be proved to exist, they would need to be explained as the result of natural selection originally, and as transmitted in accordance with the general laws of heredity. The more general effects of heredity are to be seen in the fact that one attends to moving objects, to personal combats, to all objects that are likely to be especially beneficial to the individual or to the race.

In summary, if one asks why any one object is observed at any time in preference to all the others, the answer is to be found in the nature of the external objects that present themselves. These appeal in addition to their size and intensity because of the individual's attitude at the moment, because of his experience in the immediate or remote past, and because of his inheritance. For convenience the conditions have been enumerated as if they were separate factors. As a matter of fact they are not so distinct, but one merges gradually into another. They coöperate in many ways and vary independently from moment to moment. The important fact is that if we could know the individual completely in all of his characteristics, his past history, and the influences working upon him from the environment, it would be possible to say fairly closely, even with our present knowledge, to what he would be likely to attend.

SELECTION AND ASSOCIATION

Control of Recall. — Very much the same factors are at work in determining what idea shall be revived when one remembers or imagines, as are active in controlling the entrance of sensations. In the previous chapter we showed that revival of ideas is dependent upon the succession in which the objects that are responsible for the ideas were originally experienced. These connections established in earlier experience most authorities agree to be important in deciding the order in which ideas return. If they were the only factors in controlling the recall, mental life would be much more mechanical than it is. The fact that the order of return of memory processes is so much less rigidly determined than the association theory demands has led certain schools, especially the Gestalt school, to deny that association is a real determinant of recall. They insist that a memory like an original experience is given immediately in the complete organization in which it returns and assert that previous experience has little or no effect upon recall or thought. This statement if true would hardly explain recall. It seems quite as consistent with the facts and more fruitful to assume, in harmony with traditional psychology, that earlier simultaneous and successive presentations do have an influence in determining the order of recall. This factor must be supplemented by the wider organization of experience, which unites with it to bring back just the appropriate idea. These wider influences are analogous to the conditions of attention.

The Goal Idea. — Two different theories, at present current, attempt to remedy this deficiency in the doctrine of association. One proposed by Aschaffenburg and much used by the psychiatrists would refer the determination of the course of ideas to the effect of the final idea in the series, — the goal idea. Thus if the goal of the sentence is to describe the weather, one set of words will be suggested; if the aim is to decline an invitation, another series of words may be called out, even if one start with the same word. When the course of thought leads to the goal, it is said that the goal idea dominates it; if it wanders at random by virtue of the strength of the connection between each pair of ideas, we have to do with another sort of thought. For the psychiatrist in the diagnosis of mental diseases, thinking dominated by a goal idea is an indication of a normal mind. Thinking that is not determined by a goal is a sign of abnormality. No doubt the two types constitute important practical differences in thinking. However, the designation is open to the objection that it gives a descriptive classification rather than an indication of the causes of differences in the course of ideas. It is not probable that the last idea in a series can exert an influence upon those that precede it. A force cannot be regarded as exerting an influence before it comes into being.

Mechanical Factors in the Control of Recall. — The other theory considers the same facts but explains them in terms of antecedent rather than of consequent events. We may take over almost bodily our conditions of attention and apply them to enumerate the factors that determine the selection of one possible associate from the others. Corresponding to the objective conditions, we find the factors that determine the strength of the connection between one element and those that have been associated with it. These have been shown to be the *frequency* with which the two elements have appeared together, the *recency* of their association, the degree in which they were attended to or the intensity of the stimuli that evoked them, and the age of the individual at the time they were originally presented, what Galton called the *primacy* of the association. Professor Calkins showed that the earlier in the life of a child the elements are presented together, the more likely is one of the two to recall the other.

It should be added that Galton found that very many of the ideas in a train came from youth. He kept a list of ideas that were suggested to him by objects or words, and then traced them to the time of their original experience. Thirty-nine per cent were found to come from boyhood and youth, 46 per cent from the period of subsequent manhood, and 15 per cent from quite recent events. This indicates that impressions received in youth are better retained and are stronger in their connections than those received in later years. The greater effectiveness may be said to be due, either to primacy, that is, the greater degree of retentiveness of the associations first formed, or to the greater interest in the events of the early period of life. Professor Calkins also found that primacy was an important factor in the determination of the strength of associates, even when they were formed in adult life.

Intensity and Recall. — A number of experiments from Ebbinghaus prove that both the frequency and recency of associations are important elements in the determination of the probability of recall. Intensity does not lend itself so well to experimentation, but chance observation indicates that the more intense stimulations leave more permanent effects. Under this head come cases in which the intensity is of subjective origin, is due to a strong feeling or to close attention. It has been shown that the degree of attention increases the likelihood of recall. While the experimental case for feeling is not so complete, there is good evidence from everyday life that this, too, will increase the closeness of the connection. As a result of these objective conditions, any idea or partially aroused neurone tends always to arouse some other. Were this strength of connection the only thing to be taken into consideration, it would be very difficult for the connections to be changed. The idea recalled by any given idea would be determined once and for all. The only way one connection could be broken and another substituted for it would be to permit a long lapse of time and the formation of some very strong new associations. It would mean, in any mind subject to its rule, a perfect mechanism with no possibility of breaking away from its domination.

Subjective Conditions of Recall. — This tyranny of association is tempered by the subjective conditions of attention which are effective here, as well as in the entrance of sensations to consciousness. By far the most important of these is to be found in the mental attitude of the moment, the purpose or problem that is set the individual. If one be given such a word as *dog*, a very large number of associates can readily be recalled. If, however, it is coupled with the request to name the class to which it belongs, vertebrate, animal, or some other more general term will be aroused. While if one is asked to give a member of the class, a species of dog or the name of some particular dog is spoken. There is still room for selection within the group, but the group itself is very much narrowed. Similarly, if two numbers are shown written one above the other and a line drawn beneath, as $\begin{array}{r} 12 \\ \underline{6} \end{array}$, six, eighteen, or seventy-two might be associated with them. If they appear in a check book or in other real relations, the purpose and the knowledge of what has gone before serve to determine whether one or another number shall suggest itself. If the problem is set by another, if the sum appears in a series in which one has been asked to add, subtract, or multiply, that request will suffice to suggest the corresponding figure. In any case, either the task that has been set, the demands of the situation, or the attitude that one may happen to be in, will determine which of the possible associates shall emerge. In addition to the setting, education and the social influences that are behind voluntary control of attention also have an important part in the guidance of ideas. While association provides the possible paths along which ideas may flow, these possibilities are made actualities by the more subjective conditions derived from the earlier experience and present intention of the individual, and the necessities that bear upon him at the moment. All the factors that control attention serve also to select the associates. As opposed to the Gestalt view, which denies all place to earlier formed associations and insists that experiences always appear in wholes, this does give a place to learning. It also supplements the effects of isolated connections, by recognizing the influence of wider organization. By this it recognizes the importance of the larger whole, which is the outstanding demand of the Gestalt theory.

Forms of Attention

Three Forms of Attention. — It is customary to divide attention, whether applied to external objects or to the control of ideas, into three groups, — involuntary, voluntary, and non-voluntary. In popular terms the basis of division is with reference to the presence or absence of the will. As will is a term of uncertain meaning, we can make the classification with reference to the conditions and characteristics of the attention process discussed above.

Involuntary Attention. — In general, it can be seen that the attention called involuntary corresponds to attention that is determined altogether by the objective factors. We attend in spite of ourselves because the stimulus is strong enough to force itself into consciousness, whatever the state of consciousness itself may be at the moment. Attending is against the will, against the desire of the individual at the moment. We desire to read, and the noises of the street force themselves upon us, or we desire to recall the book in which a certain statement was made, and a large number of ideas keep forcing themselves upon us. In the latter case the associations of irrelevant things are so strong that the relevant idea is kept out.

Voluntary Attention and Effort. — Voluntary attention, on the other hand, is that which is determined by social pressure. The desire to attend is not one that springs spontaneously, but is due to the impulsion of some remote end. In most cases, a struggle between the immediate and the remote good or pleasure is involved. Usually, too, as has been said, the remote good is impressed upon us by some form of social pressure. The approval of some part of the immediate social group is necessary to make the distant goal more attractive than the inherently pleasant processes that would lead us away from it. In this sense social pressure is the real motive force behind attention, the force that holds the individual to the less pleasant in the face of the more pleasant. The characteristic conscious accompaniment of voluntary attention is a mass of strain sensations, sensations which, taken together, constitute the feeling of effort. As was said in the discussion of the motor accompaniments of attention, all attention involving conflict of motives tends to arouse diffuse contractions in a number of muscles, contractions which are in themselves of no great effect upon the attention process, but which are accepted as an indication that some force is active. They make us feel active, are said to constitute a sign of the activity of the will. So far as we now know, they are not a cause but an effect, they are a sign, not of a new force, but of a conflict of conditions. That they have no good effect is evident from the fact that they do not accompany the most effective attending and, when they appear, usually die away as soon as the highest stage of efficiency is attained. Voluntary attending is due to social pressure and is accompanied by strain sensations. All strain sensations taken together constitute what we call the feeling of effort.

Non-Voluntary Attention and Interest. — The non-voluntary form of attention includes all classes not previously covered. The more important conditions are the mental attitude of the moment, the momentary purpose, education, and heredity or instinct. These seem to induce attention in accordance with the momentary attitude of the individual; they constitute in sum total the conditions of desire. The characteristic accompaniment of this form of attention is interest, a feeling of pleasure due to the lack of conflict. In so far as it is strictly interest, it is a pleasure derived from the mere act of attending, rather than from the nature of the thing attended to. Why it should come or how it originates need not concern us here; in fact, no satisfactory explanation has been given for it. One must emphasize the fact that both interest and the feeling of effort are accompaniments or effects, not causes. After all, then, these three divisions of attention are not entirely distinct. All forms produce the same effects in consciousness; they are distinct only in that in certain cases the sensations of effort or the feeling of interest accompanies them; they gradually shade over into each other without sharp line of division. Attention is a unitary process.

The Physiological Basis of Attention

The Physiological Explanation of Attention. — On its physiological or nervous side, attention may best be pictured as a preparation of one tract or set of tracts for action. The nature of this preparation in advance of the entrance of an idea varies for the different subjective conditions. The immediately preceding stimulus and the idea in mind can be pictured as due to the effect of a previous stimulation of the same tracts, which in consequence are still partially active at the moment the new excitation is received. This corresponds to the fact noted in the preceding chapter that the nervous response continues for several seconds in relatively high degree and probably for a considerably longer time in some degree. The entering stimulus, finding these tracts already active, produces a greater excitation than it otherwise would or, if several stimuli of approximately equal intensity are presenting themselves, that one produces its effect for which the way has been prepared by this partial excitation.

Attention as Facilitation and Inhibition. — The influence of attitude or purpose is the result of the spreading to a large number of associated paths of the impulse excited by the stimulus which arouses the attitude. One may think of the interaction of different parts of the cortex during attention as the effect of a widened association. As was said in the fifth chapter the excitation of a neurone not merely arouses those neurones which specifically excite movements or are accompanied by overt consciousness, but it also exerts a tendency to arouse certain neurones and to suppress the activity of others. When one is asked a question, the question, by association, tends to arouse the possible answers. This means that the impulse spreads from the auditory neurones that receive the question to the others associated with it in previous experience. In addition, it would increase the tendency to activity in a number of other neurones related to the first, and would probably check the activity of others which were not connected with the first. This would make it very likely that any stimulus that affects any of the prepared neurones would be appreciated, while all other stimuli would be less likely to be noticed than they would be if there had been no preliminary preparation. An attitude has a similar effect. When one is in a biological laboratory, the parts of the cortex that have received stimulation in connection with the observation of animals are partially active or are at least prepared for activity, while other neurones are rendered less likely to respond.

The effect of education is to prepare these systems of paths so that they may be excited by the particular stimuli or the particular occasions. It is essentially a process of organizing cerebral tracts into groups so that one entire group, as well as some particular associate, may be aroused or partially aroused by a suitable stimulus. Each of these processes may be regarded as an explanation of the selection, either from among the stimuli which seek to enter consciousness, or between ideas that are associated with the particular idea that serves as excitant. Thus on the nervous side, the course of impulses is determined by the action of very large numbers of neurones, many of them very remote from the neurones which are actually the seat of the processes attended to. The cortex acts as a unit rather than in parts, just as, on the side of consciousness, practically all experience unites in determining the course of any single element of consciousness.

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CHAPTER XIII

THE UNIT OF EXPERIENCE

What Is Primary in Experience? — Up to this point we have been dealing with the laws of mental life treated as if they acted in isolation. We must now consider how these laws are represented in the actual concrete experience. Two theories are important contestants for acceptance on this point. The older view is that an object is appreciated as the result of the arousal by the sensation presented of older retained elements through the laws of association. On this view the object would, for the man who sees it, be built up out of elements, some of which come directly from the senses and others from the revival of old experiences. Opposed to this is the Gestalt theory which we have referred to frequently which asserts that an object or other experience is given as a whole that cannot be farther analyzed into parts. It comes immediately and receives immediate acceptance.

Neither view can be understood in this bald statement, and the first is subject now by almost all of its supporters to considerable modification. Every one admits that we are directly aware not of sensations and images as elements but always of things as wholes. The analysis into elements is only for the purpose of making clear what may have been the way in which the event or object we experience was developed into the unitary whole. The changes in experience with interpretation are important to bring the problem of the final unity into prominence. Such a simple fact as that the size of the object seems within wide ranges of distance to remain approximately the same as it goes farther away from the eye in spite of the fact that the retinal image decreases regularly with the distance indicates that the sensation alone cannot determine what one sees. What is important is the total reference.

Individuals may start with the assumption that what we know is definitely limited to what are called the structural phases of consciousness or experience. This theory assumes that there is on the retina an image of a specific size. The image, we know from the laws of optics, must be present and also we know that as the object that casts the image recedes, the image becomes smaller and smaller. It is also assumed that a sensation or group of sensations in consciousness corresponds exactly to the image on the retina and varies as that image varies. But what one is actually aware of is not the group of sensations diminishing in size as the object goes farther away. Instead one sees an object that retains the same size and becomes more and more remote.

Image and Meaning. — Since Berkeley it has been recognized that one has these two aspects of experience. One is the actually appreciated object that is regarded as outside and as constant in size and coloring, the other is the group of sensations that we assume to be the basis of the perception, and which observation under careful conditions and with the right attitude shows to be present. Brentano made this distinction the universal criterion of the difference between physics and psychology by asserting that for physics anything is what it is, while for psychology the elements are of value only for what they mean. In our special case the image on the retina and the corresponding sensation mean an object of a constant size at a varying distance, although the image and sensation vary continuously in size and remain in the same place, *i.e.*, on the retina. This division of meaning and image runs through all psychological processes, perception, and recalled experiences. Certain authors have insisted that the important and true phase is the image or structure, while the meaning is merely a shadow and in consequence is unimportant. Titchener held this point of view. The Gestalt school holds exactly the opposite opinion. The real experience for them is the completed experience, and the structural phases, sensations, and images do not exist.

Is Meaning or Image Primary? — If we accept the existence of image and meaning as two aspects of each experience, it is necessary to see how one can be derived from the other. We may assume the existence of structures, of sensations, and recalled images or centrally aroused sensations and then try to develop a notion of the way meanings may be added to them. In practice the appreciation probably develops in the other way. We are aware of the meanings first and then build up theories of the presence of sensations to explain how the meaningful experience originates. So far as the adult can remember he has always seen the object as of the same size no matter at what distance it may have been. He knows that the perception depends upon images on the retina only after he learns a good deal about the retina and the physics of light. However they developed, acceptance of the two aspects seems demanded by the facts and by the modern theories. We have the alternative of assuming that the meaning or Gestalt is all and content ourselves with saying what we can of the wholes as we find them, or of accepting the images as actually existing, and discovering a method of explaining how meanings might be added to them.

Reference in Space and Time. — The problem takes approximately the same form for the first experience in what we call perception and in the memory processes. In perception or the experiencing of concrete objects, what is thought of is projected into space and is regarded of standard shape and size. This thing as percept is approximately the same no matter how its distance or the surface which it is projected upon may vary. In the memory or thought process, the image is always of the present, but the reference may be to the past or the future or be timeless. It too may be projected to any place. In that respect it is more independent than the percept for the percept is restricted to the immediate neighborhood. The visual percept is always in the immediate field of vision; the source of auditory sensations is limited in its localization to the range of the sound waves; the tactual percept is restricted to the surface of the body. The memory and imagined objects are independent of space and time in their reference. One can remember an event as taking place wherever it occurred and at any time. An imagined event or one that is developed through reasoning can be assigned to any place or to any time whether the individual who imagines it has ever been in that space or lived through the time or not.

The Permanence of Objects. — If one assumes the existence of the image and the meaning, it is necessary to consider both what the nature of the meaning is as an object or existence in itself and how it originated, and to understand how the thing meant is connected with the image or structure. In our instance of the constant size that is assigned to the varying retinal images as the object moves away, constant area is the meaning, the varying image the structure. Similarly a cross always seems to have a right angle no matter from what direction it may be seen or how it may turn. A bit of paper always seems to be of about the same shade whether in sunlight or shadow, although its actual brightness varies strikingly. Our first question is why we see objects thus standardized and independent of the changes in the sensations.

This problem verges on the question of the nature of the external object in philosophy. The *thing* is in many respects just the *meaning* of the image. It is the object that we think of as retaining its true size no matter how far it may be away from the eye, and no matter how its image on the retina may vary. If we make an empirical interpretation, we may assume that we think of the object as always being the same size because we can test it with the fingers or measure it and find that it is always the same. Or we may assert that we assume that it is always the same size because we can think of no way in which it could change its size really as it varies its distance from the eye. However it happens, we know that the same shape and size is always ascribed to the same object, no matter how much unusual conditions of presentation may distort the image that it offers to the retina. Generalized tendencies to corrections of parts of objects are also applied to parts of all objects. Acute and obtuse angles all tend to become right angles, shadows are overlooked or allowed for, differences in color are not noted, and all of the stimuli from within the eye itself escape notice.

The Development of a True Notion of an Object. — Together these phenomena may be regarded as indicating that there is a tendency for the perceptions to be standardized. An object that is regarded as the same, assumes the identical form under all conditions. This statement takes it for granted that at first the same object will present to the child a number of divergent forms or outlines. It may also be further assumed that at first these divergences would attract notice. Then they would be identified as belonging to the same object. After a time the divergent characters would be overlooked and finally only careful observation would show that these departures from the standard are present. On this view the object would be built up through a process of experience. The different presentations would be identified as belonging to the same object, then some one presentation, probably the one that was most frequent, or best suited to give a complete view of the whole, or that had best stood the tests of examination by other senses, and of intentional construction as objects were built, would be accepted as the true form. That would gradually replace the various divergent presentations and be accepted as real. Then the sensory impression, no matter how divergent from that true form, becomes merely the sign that the true form is present, and the true form or real object is at once seen. The image is completely overlooked.

The Development of Concepts. — A very similar process can be shown to make possible the development of the way in which we represent a class of objects or series of attributes or characteristics of objects. Here we deal not with different presentations of the same objects but with presentations of different objects, at different times. At first the separate objects are assumed to be altogether different. In time, objects that at first were regarded as belonging in altogether different groups are seen to have points in common. Gradually the common points are more prominent than the differences and the object is named as belonging to a class with some special indication of the specific characteristic that marks it as different.

The Laws of Development of Concepts. — Hull studied the way in which subjects saw common elements in Chinese symbols or ideograms. He chose series of figures with common elements or radicals and presented them to a number of students with the request to prepare to reproduce them at a later period. As each was shown, a nonsense syllable was given that was the same for those with the same common element. The series were repeated until the symbol evoked the nonsense syllable given with it spontaneously. The procedure made the formation of concepts incidental since the observer assumed that he was learning the syllables to the point where he would be able to reproduce them. As they were repeated the observers came to see that each of the members of the series had a common element. In one set of experiments with one group of students, the figures were shown with a regular progression from the simpler to the more complex symbols, in another set the ideograms were arranged in the order from the complex to the simpler. It was found that in all cases the common elements were recognized more quickly and learning took less time when the simple to complex order was followed than when the order was from the complex to the simpler. When in another experiment the common element was shown for itself in one series and thus the concept formed artificially and in another series the observers were left to discover the common elements for themselves, it was found that the concepts were developed equally readily by each method. The only difference was that the observers could draw the root figure or common element more readily when it had been given to them separately than when it had been necessary to pick it out from the concrete setting. The gradual recognition of common elements and the reference of the different concrete units to the general class is characteristic of concept formation in everyday life.

Types Develop in Recall. — Another factor that is active in the formation of these types or concepts is seen in the transformation that goes on in forgetting. Crosland made a study of the changes that a concrete object undergoes in the attempts to recall it after different lengths of time. He found that there was an increasing tendency to develop a type image in place of the concrete ones. This consisted in dropping certain details and replacing them by others which were more consistent with the whole. There was thus developed a very clear schema of the object to be recalled, which was thoroughly consistent with itself. There might be a background of vaguer elements that came in now and again, but these were subordinate to the framework or type which was definite and clear. This working over of the original impressions, when one deals with a number of objects that belong to what come to be regarded as forming a class, makes the development of a concept or type the general rule. The elements or phases that are common to the group are remembered and emphasized, those that are not common are gradually forgotten or suppressed. In consequence, one recalls the common elements or the type whenever one has occasion to think of the group as a whole or even of a single member of the class. In the cases in which single members are recalled, the class is thought of first and then the characteristics which mark off the individual from the class. Thus the defects of recall come to make possible of themselves the development of a concept.

Things Are Types. — We have evidence then that what we call things in perception are the products of an unconscious process of adjusting separate experiences to each other and to older memories until a construct is found which harmonizes them all. This adjustment gives rise to a definite standardized unit in the case of simple objects. In others it develops a law which may be applied to all objects under all circumstances as for instance the retention of the same size no matter what the distance, and the constancy of color without reference to the illumination, the omission from consideration of the shadows from the retinal blood-vessels and after-images. Similar general corrections are seen in the tendency to see all intersections of straight lines as right angles without reference to the real angle of intersection and numerous others. All of these tend to give every object a standard form whatever may be the specific circumstances of observation. This correction makes for the development of the real things in perception. The differing forms of presentation of the same object under varying circumstances at the successive presentations are compromised to constitute the object accepted as standard or as real. This product of experience is seen no matter what the actual form of the image may be.

Type and Concept. — In the same way when different objects that are in some way similar are seen at different times, each in the course of time tends to be referred to the other. The common elements are seen in each. The divergent parts are suppressed or seen as supplementary to the common features. A type for the class develops in this way which is related to the separate objects in much the same way that the type in perception is related to the separate presentations of the same object. The correction is much less complete. The differences are not overlooked as they are in perception of the same object. The degree in which the similarities dominate the differences varies from case to case. Sometimes as with German police dogs by the man who is not a dog connoisseur, the species alone is noticed without any awareness of the sub-species or individual. By the connoisseur the sub-species or, if the individual is familiar, the particular dog is recognized. In practically every case specific marks combine with the general class. The more familiar the members of the group, the greater the likelihood of recognizing a particular. This use of the concept, after it is once built up in the appreciation of the individual as well as of the group or class, is very like the use of the type in perception and subserves very much the same function.

The Type Identified with the Real Object. — In perception and in many instances of memory, imagination or thought, what we accept as the real experience is a type obtained by a process of construction from many different experiences. This type may be a fairly definite image in which details may be appreciated. In that case it replaces the actual visual image which must be presented on the retina and in sensation. That the imperfect image is actually present may be proved by careful observation (introspection) and can be demonstrated from a knowledge of what the image must be. In certain cases, as in the Helmholtz checkerboard figure (Fig. 88), it can be experimentally demonstrated that a real object is actually corrected as we prove the retinal image to be.

Selection of a Type. — Where the image is thus corrected by the concept or type, the question must be raised as to how the correction takes place. The answer is that the established type is reinstated by the strength of the previous connection under the influence of the attitude or setting in which the stimulus presents itself. The two coöperate as they do in all recall. There must have been a previous connection in every case. Where there are two different types that might be applied in a particular case, that one is chosen which harmonizes more completely with the situation at the moment of perception or recall. Sometimes the correction is piece meal. A part of the total has been definitely established as a standard and that supplements a part of the total, and other stand-

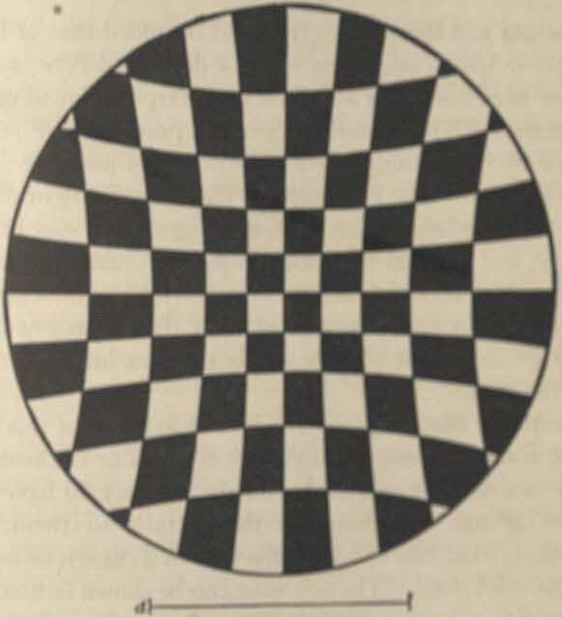

Fig. 88. — To show the distortion in the periphery of the visual field. Hold the center of the figure at a distance from the pupil equal to the line below and the lines are all straight and the angles right angles. (From Helmholtz.)

ardized parts are drawn upon to fill out other parts. At times the type presents itself as a unit. In all cases it must be emphasized that the thinker is aware only of the completed experience. He knows nothing of the way it is built up. He does not distinguish between the cue and the completed structure.

Meaning and Content. — It should be added that at times, possibly in most cases, there is not a developed type, such as we have been describing at call for the interpretation of the cue or situation. The immediate sensory processes are supplemented by irradiations which constitute the meaning. This is less frequently true in perception than in memory or reasoning. Here the content is a series of images which may be clear or hazy, and the real experience is merely symbolized by the images. The very fact that one knows so little of the character of one's images and is so sure of what they represent is sufficient evidence that what is real is the idea intended rather than the images.

Words and Meanings. — The best illustration of this is the use of words. Words are obviously of no value in themselves either as sounds or as visual symbols, yet they do have great power through the meanings that attach to them. The meaning is what is in mind effectively even if there is no content but the word itself. The reference can be shown indirectly to be dependent upon several factors. In the first place when the word is unfamiliar no meaning attaches. Previous experience with the word must be an element in the meaning. A second factor is the context. The same word in different connections has different meanings. *Can* as an auxiliary verb and *can* as a receptacle have very different effects; *can* as a slang word for dismissal gives still a different meaning. Which meaning shall be present to the individual who hears will depend upon the context, the preceding words and the general situation in which speaker and hearer find themselves.

Regarded objectively and from the standpoint of conditions of arousal, meaning develops as a result of effects left by previous experiences with the word and of the preceding incidents at the moment it is presented.

Meaning a Felt Possibility of Recall. — While these give the conditions which determine what meanings shall attach to a word, the question of what the meaning consists in is left open. In some cases something like the type or concept, a definite mental image, is aroused before the meaning of the word takes form. In many other cases there is no such added picture or content of any sort. The word itself when it is familiar evokes a definite aura which in itself makes clear what is meant. This aura of meaning may be in some cases the evidence that specific images or old events might be aroused or might present themselves if time were allowed. The meaning may consist in nothing more than the awareness that bits of knowledge would come definitely to consciousness if permitted. This corresponds to the way in which a student may review a course. When one topic is suggested, he feels sure that he knows that and does not take the time to run it over. The knowledge he has reflects itself in the certainty that he could recall it if he would and he does not attempt it. Meaning of a single word is probably in part a similar awareness that the objects connected with the word would come if given a chance.

Both forms of meanings undoubtedly exist. In many cases a meaning is just a type that is aroused by the word or other mental content which is the occasion for the meaning. In other cases, it seems certain that meaning is of the aura character, that it is something that diffuses from the structure, and assures the thinker or the observer that the core implies more than it is in itself. Probably in no case is any bit of mental content without this irradiation. In some instances the image almost vanishes and practically all that is present is the certainty of what is intended or meant. In other cases the picture is perfectly clear and seems almost self-sufficient. Even in that maximal dominance of structure there is always a reference to other experiences without which the content would be dead and valueless. James long ago pointed out the effect of this halo of meaning about a word by his statement that a word gazed at continuously for some minutes seemed to lose the meaning and to become moribund. It loses all its value for reference. Trying the experiment brings out very clearly the difference between the meaningful and meaningless in words. This is on the assumption that James is right that what results from the staring is loss of meaning.

Meaning Dominates Consciousness. — That we are not ordinarily accustomed to distinguish between the structure and the function, the content and its meaning, is due to the fact that we are always interested in the reference or meaning and not at all in the structure. We are interested always in the message that a word brings, just as the signal man is interested in the message of his flags and is little concerned with deviations from their color, or in the worn spots on their surface. Similarly it is the references in percepts which concern the observer, not the mere images of sensations which make that meaning possible. It is only when the psychologist becomes interested in how percepts are aroused and studies them with reference to the structure of the sense organ, that he notices or cares to know how much is true image and how much is meaning. Then only does he become aware of how complicated the problem is.

Meaning a Product of Experience. — One may naturally speculate as to how this awareness of reference develops. That awareness is modified in many ways by the connections with events and experiences beyond the immediate structural element is generally agreed. The Gestalt school makes belonging to a whole, as we shall see, characteristic of all awareness. It would require only a slight modification of their doctrine to make all consciousness the expression of the effects of these connections. If one change this slightly and translate into terms of the traditional neurology, it could readily be argued that consciousness is the accompaniment not of the activity of the neural elements as such but the accompaniment of the action of neurones in connection. It has long been argued that all of the essential activities of the nervous system are dependent upon the point of connection between neurones, the synapses. It would change the theory only slightly to assert that not the response of units accompanies or makes possible consciousness, but only the response of masses of these units in harmony. That would mean that consciousness accompanies the spread of associative discharges from unit to unit throughout the group. The Gestalt school and Lashley would deprecate the mention of units. This objection which is largely formal could be met by asserting that the irradiation through masses of active areas of the nervous system is the essential determinant or accompaniment of consciousness. Meaning then would result from the opening or partial opening of connections between the central structure and the other areas that are aroused by it. In this it would be little different from any other consciousness.

Type and Gestalt. — Different in principle but in many ways like this theory of concept and meaning is the Gestalt or configuration theory. This theory goes back to a statement of von Ehrenfels published in 1890. Von Ehrenfels made use of an observation of Mach that form seemed to be independent of the lines that made it up. He reproduced Mach's statement that a square seems to be changed in shape as it is seen on its base or on a corner with the diagonal vertical. Possibly clearer is his illustration that a melody seems the same whether written in a major or a minor key although all of the notes in the two cases are different. Von Ehrenfels argues from these facts that the form or Gestalt[1] has an existence independent of the sensations upon which it seems to be based and which compose it. He was content to regard these forms as elementary and only slightly dependent upon the sensations with which they occurred. Similarly all ideas of relation and more general concepts were called Gestalten and regarded as immediately known and not farther analyzable or describable units of consciousness.

Imageless Thought. — Some ten years after von Ehrenfels wrote, the Würzburg School under the direction of Külpe showed that under certain circumstances an idea or meaning might be presented without any specific content. When an individual was asked to solve a mathematical problem or come to a decision on a complicated philosophical or ethical problem, he might be sure that he had the answer and have no concrete imagery present at all. This they called imageless thought. Imageless thought may be regarded as related to the image-meaning theory as an instance in which the meaning or reference is present without the structure or image. It is related to the Gestalt of von Ehrenfels as if it were a Gestalt without any basis in sensations. The experiments made by this school tended to emphasize the importance of the meaning or reference since they made it possible to think of either meaning or reference as existing without the image or other structure which had previously been regarded as essential to the meaning or Gestalt.

Gestalt as Immediate Unit. — In the period beginning in 1913, there developed a new way of looking at consciousness as a whole, which took over the word Gestalt and much of its meaning. This practically reverses the traditional theory by making what is meant or the reference the only real content of consciousness and denying existence to the structural elements of sensation and image which the traditional psychology had made the assured basis of mental life. This modern Gestalt theory differs from von Ehrenfels in so far as the form or configuration is made self-dependent and not considered as based upon the sensations. The square is not something added to the four lines that seem to compose it. The figure or form in itself is an independent existence. Sensations do not exist for the Gestalt theory, nor are there any associations between the elements. Since there are no elements there is nothing to connect or to associate. On the Gestalt theory there is no problem in psychology but to discover and enumerate the different types of Gestalten. Experience is just a series of these units which cannot be analyzed or described. There is little hope of determining the laws by which they succeed each other. They merely come.

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[1] Gestalt is the German word meaning *form*.

So far the upholders of the school have been so occupied in refuting other statements about consciousness that they have had little opportunity to give any positive characteristics. If we put together what they have said, it seems easiest to connect the Gestalt with what we have been discussing by stating that the Gestalt corresponds to the meaning of the mental states rather than to the structural aspects of the mental states. The Gestalt school would deny the distinction between meaning and structure, since there is but one process. If one states the position in terms of the Brentano theory, the Gestalt is more like what Brentano called meaning than it is like the traditional image or structure. If we were to choose between what we have called the type and the mere irradiating or aura form of meaning, it would have more of the characteristics of the type. Where it represents spatial forms it can be pictured. It also shows certain of the functional characteristics of the type. There are good Gestalten and bad ones, or better and poorer. The poorer Gestalten all show a tendency to change into better ones. This is similar to the tendency for memory images to approximate types by elimination of the divergent images.

Forms of Gestalten. — A Gestalt includes unitary experiences of all sorts. The term Gestalt was first applied to the awareness that lines moved or seemed to move from one position to another in a moving picture. When a line is shown in one position and immediately after another line is shown in another position near by, the first line seems to move from its own position to that occupied by the second. This apparent movement is a Gestalt. The perception of an actually moving line would also be a Gestalt. Simple geometrical figures are also Gestalten. A circle, a square, a triangle are Gestalten. The criteria of good and bad can be applied to these figures by simple experimental tests. It is found that a slightly shorter exposure is needed to see a circle as a circle than to see a square as a square. If a circle be exposed for .124 second, it will be recognized while .128 second is necessary to recognize a square, and still longer to recognize a triangle. On this basis the order of goodness is said to be circle, square, triangle. Another measure is the amount of illumination required to recognize a figure. If the light be made so dim at first that nothing can be seen and then be gradually increased, the first form to be recognized is the circle, the next, the square, and last the triangle.

The Gestalt as Dynamic. — A Gestalt is not always a static thing. If parts of a Gestalt be given, it tends always to complete itself. The direction of completion again is always towards the perfect figure. If a circle which lacks a part of a circumference be exposed under a very faint light or for a very short time, the gap will be filled and the circle will be seen as complete and perfect. On the same principle if an ellipse be exposed for a short time or in a dim light it will be seen as a circle. The perfect Gestalt tends to be substituted for the less perfect one. Similar in character is the statement that

Gestalten may be open or closed. An open Gestalt is one that is in some way incomplete, as the circle that lacks a part of its circumference. This term is used more metaphorically to apply to problems that are not solved. Any problem involves an awareness of itself together with the appreciation of its incompleteness. The solution of the problem completes it and gives it perfection. This last metaphorical use of the term affords a means to Lewin of stating many acts and emotions in terms of Gestalt. All movements that are not mere reflexes are to be looked upon as the outcome of incomplete Gestalten which strive to complete themselves. The strains of the inadequate state give rise to emotions, and activity results from the tendency to complete the Gestalt by action.

The Whole and the Part in Gestalt. — One can deal with Gestalten in no other way than by enumeration and description. Even description is limited, for the Gestalt has no parts or at least the parts do not determine it and so need not be mentioned. There seems to be a division of opinion as to whether a Gestalt does or does not have parts. If parts exist they are the result of tendencies for the Gestalt to break up to form other Gestalten. The Gestalt is the first and determining factor, the parts are subordinate and secondary. The whole determines the parts, not as the result of an interaction between the parts but by virtue of the dominating overlordship of the whole.

Experience and Gestalt. — A still more striking difference between the interpretation of the units of experience as meanings or as types, is the importance ascribed to experience in the two theories. As we have seen, meanings and types or concepts are assumed to grow from experience, to be gradually evolved through dealing with objects. The Gestalt is asserted to be uninfluenced by experience but to be given from the beginning in its full perfection. This assertion rests for its proof upon a long investigation by Gottschalk. Gottschalk showed his observers simple figures a great many times, some of them several hundred times. Then he showed the same observers complicated figures in which these simpler ones were contained as parts. He found that if the single figure were sufficiently obscured in the whole, as by making its parts belong to two different elements of the total, it would not be recognized, no matter how often it had been shown alone. Thus a figure A was shown a number of times, then figure B was shown. If you look a sufficiently long time you will be able to discover A in B. Probably the experiment only demonstrates the importance of attitude. When looking at the figure as a whole it is very difficult to take the attitude of looking for the parts also. Familiarity is not so strong as attitude in determining what shall be seen.

We shall have frequent occasion in the following discussions to insist on the importance of these larger unities in consciousness. However we interpret them, it is these larger units that constitute what the man who thinks in the concrete is interested in. We need not here settle the question which of the views we have mentioned is more in accordance with facts. Whether it is better to assume that an object or a memory is a type or concept that has been built up as the result of numerous experiences with things, whether it is a mere reference to groups of experiences made possible by the connections of the core of structures to groups of older experiences that are meant but not recalled, or whether it is a unitary experience is highly important. Now, however, we are more concerned to show that the realities of life are not elements but units. We see these larger units in perception, we recall them in memory and we use them to solve problems and to arrive at conclusions in reasoning. The common factor in all of them is the immediateness with which they are recognized, the fact that they are self-contained. We shall have occasion to use the principle, in whatever form, in each of the processes involved in knowing to which we must now turn.

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CHAPTER XIV

PERCEPTION — SPACE

GENERAL THEORY

THE primitive psychological process that gives awareness of objects is known as perception. Perception is primitive since it is obtaining knowledge of an object in the concrete. It is the first and simplest knowing operation. Sensation is theoretically simpler since it is assumed to depend upon the action of a single sense organ or sensitive structure. Sensations are not known so directly. On the contrary they are the products of abstraction and experimentation which are necessary to free them from the other elements that come with them in perception. A percept is the concrete object as we appreciate it or as we believe it to exist in outside reality. It comes always, to be sure, as the result of immediate sensory excitation, but is regarded as involving more than the sensation. It may be due to the stimulation of any sense, although it is usually initiated by one of the external sensations, extero-ceptors.

Perception a Unit Process of Experience. — In the light of the discussion of the last chapter we may assert that perception is the first of the unit experiences. In terms of the different ways of naming the unit experience, it may be regarded as a meaning, or as a type, or as a Gestalt, in so far as these are not different ways of presenting the same elementary fact. It is a meaning since in perception we are concerned, not with the structural components or sensations and images, but with the object in the physical world that they represent or refer to. It is a type since the percept is never limited to the mere sensations that are acting at the moment, but deals with these sensations as they have been corrected and standardized in past experience. It is a Gestalt, as it is a concrete unit of experience, complete in itself, and self-consistent in all of its parts. These three theories or ways of approaching perception are not to be completely harmonized with each other, but each is valuable since each offers an aspect which agrees with the observed facts of perception. In this connection the meaning and the type designate approximately the same facts. Usually in perception the thing meant or referred to is a type. The percept is a perfectly clear image, in which all of the details stand out definitely.

Perceptions Involve Memories. — In some cases concrete memories can be seen to supplement the sensory elements of the percept. When a man blindfolded feels a rough bit of paper, visual images are supplied to interpret what he feels. Although the sensations are cutaneous, the interpretations may be almost entirely visual. Something similar is most certainly present in filling the blind spot. As was said in Chapter IV where the optic nerve enters the eye, there are no rods or cones and hence no possibility of receiving visual sensations. Still no one is aware even that he has a blind spot until he reads about it or is told of it. Even then he continues to fill the blind areas with images on the analogy of the objects seen in the surrounding area. If one looks at a broad line so that part of it falls on the blind spot, he sees it as if it were continuous. If there be a break in the line in the area which falls upon the blind spot, the gap will not be noticed.

The Type in Perception. — Most striking and important is the evidence that a type is evoked by the stimulation that gives rise to the percept. As was said the type may be regarded as a standardized object that has been built up gradually to harmonize with all the experiences we have had of a given object. One of the simplest illustrations that can be given is the way in which we see the top of a table or other rectangular surface. It is on the retina a figure with the front and back sides approximately parallel but with the other two sides slanting towards each other and usually making obtuse and acute angles with the front. This figure is almost always finally interpreted as a rectangle. We could never see the figure in such a way as to give this impression. The nearest approach to it would be when we have one eye directly over its center. Even then the sides would not be straight lines but would be bent because they are received upon the curved surface of the retina. This figure with which we replace the rectangle is something that we know from all of our experience must be the object as it exists in the outside world. Even if we never have seen that object in just that way, we nevertheless regard that as its true form since when we test it by building it or by fitting it into corners that we know are square, it proves to be rectangular. In other words we accept as real the construction that has proved on earlier test to harmonize with all of our experiences of that object. We see and hear by replacing or correcting our sensations as our experience proves that we must correct them if they are to explain the world as we have known it. It is little more than fair to say that we see these corrected concepts rather than actual sensations. Instances which prove that we see these corrected and harmonized results of past experiences will be found to be numerous in our discussion of perception.

Perception Implies Movement. — These corrections in the light of wider experiences always involve a considerable amount of reference to action. The tests that we apply to the objects are frequently of a type to involve action. We know what objects are like because we try to manipulate them in various ways. One may go farther and argue that, since to every sensation there is some form of motor response, perception, too, must involve some motor activities, and that these motor responses are an essential part of our interpretation of the object. The behaviorists would go so far as to add that all that there is of importance in the percept is this reaction or group of reactions. Since their theory leaves little room for knowledge, it makes relatively slight difference to them whether we perceive through our movements or not. One must insist that response to movements modifies our knowledge and that the nature of the responses is an element that cannot be neglected in a discussion of perception, although it is not always possible, in fact has seldom been possible, to detect the elements that movement adds to the perception in individual cases.

The Common Aspects of Perception. — It is convenient in the discussion of perception to recognize on the one hand the general characteristics of all percepts, and on the other to consider the laws that apply to the perception of particular things. Psychologists generally recognize that all objects involve the perception of space and time. Space and time are such universal phases of all perception and of all things and events, that they have sometimes been regarded as real existences. We are interested only to indicate that we can discuss the laws that apply to all perception under these two convenient heads. For space we have the general questions as to how we appreciate the position of stimuli, how objects change in size and shape, and how we appreciate the distance of objects from us. The problems in connection with time are as to how durations are perceived, and the influence of duration upon our appreciation of motion and of rhythm. Movement, too, is a common aspect of much of experience, and may be given a unitary treatment. It involves phases of both space and time, but is essentially peculiar. It is an advantage to consider the general aspects of objects and events together, since what holds for one object will hold for all. We may begin with space since it offers more varied problems.

PERCEPTION OF SPACE

Problems Concerning Space. — Space is appreciated by means of at least four senses, — touch, vision, audition, and the kinæsthetic sense. Of these, vision gives the most accurate and complete appreciation, touch combined with the kinæsthetic impressions stands next in definiteness, and the auditory space comes last. In actual practice all objects that are recognized as objects are thought of as existing in space, whether they are actually sensed or merely recalled. In the senses not mentioned, the spatial aspects are ascribed to one of the more definitely spatial senses; thus tastes are referred to the tactual impressions also received from the tongue, — or are somewhat indefinitely referred to space in general. Odors are usually ascribed to objects, but the localization is always uncertain and the quality may be thought of as independent of the organ, as general or all pervasive. Not only are the subordinate sensations referred to sight, but there is much cross reference between the higher senses. Different senses predominate in different individuals, but in all space interpretations several senses are involved.

Three different aspects of the space problem present themselves, although for sight and kinæsthetic impressions alone are all these to be considered. These three are the appreciation of *position*, of *extent* in two dimensions, and of *distance* or depth, the third dimension. The skin appreciates position and extent alone; the ear, distance and direction alone. We can start with the simplest problem in each sense and transfer what may be gained from that to the more complicated constructions.

Perception of Tactual Space. — Theoretically simplest of the space problems is the appreciation of the position of a point upon the skin. Experiments have frequently been made to determine how accurately a spot upon the skin may be localized. If one attempt to touch a spot on the skin, one will make an error that averages a centimeter or so on the wrist or on the back of the hand, is smaller on the fingers, and considerably larger on the portions of the body ordinarily covered by garments. This simple experiment indicates two facts: first, that there must be some way of knowing where the point touched is and that this knowledge guides the movement; and secondly, that the localization is not absolute, that it is subject to error, and more or less variable. One of the first theoretical attempts to determine what it is that gives a knowledge of position was made by Lotze. Lotze pictured the self as somewhere in the brain and as receiving impressions over the nerves from the surface of the body. Such a self might be thought of as constantly questioning what part of the skin gives rise to the sensations it receives and seeking for signs that indicate their origin. Lotze asserted that the sensations received from different parts of the skin had different qualities. These different qualities were not described very definitely, but apparently are due in part to the character of the skin and the amount of tissue that lies between it and the bone. Lotze called these qualities, 'local signs.' If you try for yourself to discover a difference in quality that corresponds to different positions, you will probably fail. You know immediately where the touch is, but do not know how you know. Lotze's theory has value as a graphic way of stating the problem, but the fundamental assumption that the knowing individual is shut away from the surface and must appreciate positions by specific marks is an over-simplification.

The Determinants of the 'Local Sign.' — Indirect considerations indicate that the local sign is in some way related to the nerve or nerves stimulated. When a member has been amputated, the sensations from the end of the nerve in the stump are still referred to the original endings in the missing member. When a portion of the skin has been displaced by a surgical operation, as in making a new nose from a flap of skin on the forehead without severing the nerves that supply it, sensations from the displaced skin will for a time be ascribed to the old position. It is true, too, that the accuracy of localization is greatest where the nerve endings are most numerous. These factors might be explained on Lotze's assumption that each nerve had a 'local sign.' They also have been interpreted to mean that localization is due to the movements called out reflexly. If each point on the skin were connected with a set of motor neurones that would cause the hand to move to the point touched or that would call out a slight movement toward the point, the movement might be used as a sign of the position. This motor theory receives some support from the fact that animals whose brains have been removed, and men in their sleep, will touch the point stimulated with a fair degree of accuracy. That it alone is not sufficient is probable from the fact that the normal animal makes the movement with greater accuracy. Still a third theory would make the localization due to the association of other sensations with cutaneous excitation. Often a picture of the point touched comes immediately upon contact.

Each of these facts is suggestive. However, no one alone or all taken together would suffice to explain the localization. Each refers us to another sense when we ask how we know, and there is just as little in that second sense to tell us how we know the position as there was in the sense from which we started. It is a problem that must be answered in terms of the type or Gestalt. In the course of experience, if we accept the type theory, touch has been referred to sight, and sight to movement and to touch. Finally all of the experiences have fused into a consistent interpretation. This constitutes our type of position for the given spot. After it is developed, a contact on the skin evokes that type, as does also the visual picture and the kinæsthetic impression of the movement. In part it is the possibility of recalling position from any sense by stimulation of any of the others at a suitable place. The Gestalt theory makes the same statement except that the Gestalt would have arisen without experience. It is just the immediate awareness that arises as stimulation is applied to skin or retina, or as a member moves.

The 'Limen of Two-ness.' — Much the same problem meets us in connection with the appreciation of a minimal extent. This has been studied by determining the least distance at which two points might be appreciated as two. Weber, who made the first experiments, found that this distance varied from approximately 1 mm. on the finger tips and tip of the tongue to 40–60 mm. on the middle of the back. In general it was larger on the portions of the body ordinarily covered and, on the limbs, decreased regularly from the center of rotation downward. Volkmann noted that it varies approximately with the amount of motion of the member and of the parts of the member in question. Goldscheider repeated the experiments by putting the points of a compass upon pressure spots, and found that two points might be distinguished when the points were on contiguous spots. His values varied from 0.3–0.6 mm. on tongue and finger tip to 4–6 mm. on the back. Later experiments by von Frey indicated that these values were too small unless the stimuli were applied successively. In these experiments, as in comparisons in general, successive stimuli are judged more accurately than simultaneous stimuli. It is also to be noted that practice and suggestion have marked effects. Values may be reduced one half or more in a few weeks' practice. It is seen, too, that practice on one part of the body will have an effect upon the symmetrical areas that have not themselves been exercised.

Theories of Appreciation of Extent. — Appreciation of extent like the appreciation of position has been explained by transfer to other senses. The limen of two-ness is not to be referred directly to the appreciation of position in terms of a simple local sign, for the minimal distance that can be appreciated is approximately the same no matter what two points within a given area are touched. Practice reduces the minimal distance that may be appreciated. Larger extents have been explained by reference to movements made either by the member that receives the stimulation or by another member, a finger, *e.g.*, that is moved over the extent. They have also been explained as due to reference to vision. If you are estimating how large a surface applied to the skin of the hand is you will probably call up a picture of how large it would look. Visual images in themselves are not of course a complete explanation since some characteristic of the cutaneous impression must make it possible to call up the correct picture. The blind must also have only the immediate tactual appreciation as a basis and they are much more accurate in estimating distances on the skin than are the seeing persons.

An illusion of unexpected character in the tactual space phenomena is that filled space for touch seems shorter than empty space. For vision the illusion takes the opposite form, filled space is apparently greater than empty space. If you apply to the skin of another two points with no other stimulations between them, and then two other points the same distance apart with other points on the line between them, the empty space seems the longer. There seems no reason why either the movement or visual space should be shorter when the space is interrupted. Possibly the Gestalt theory might assert that the tendency was for the stimuli to concentrate about the center of gravity of the Gestalt, but this seems rather metaphorical than convincing. Probably organization of the different separate experiences to constitute a type or a harmonious method of interpretation provides an explanation for distance as for position. Again we have the alternative of the Gestalt, which is present in advance of experience and comes at once as the stimulus is applied.

Retinal Local Sign. — If one is to explain something of the spatial perception on the skin by reference to the influence of vision, it is also necessary to understand how position and extent may be perceived on the retina. The same problems meet us here and many of the same facts are present to provide the data for discussion. There is a lower limit of distance that must separate two points if they are to be perceived as two. On the fovea if two dots or lines are nearer together than .004-.006 mm., or an angular distance of 60″-90″, they fuse into a single line or dot. This may be regarded as the 'limen of twoness' for sight. The effects of the inability to distinguish lines and points closer together than this minimum can be seen in the ability to distinguish letters in reading. The normal eye can read letters when the width of the separate lines and the distances that separate them are each 1′. The Snellen types in the adjoining figure can be read at a distance such that the lines are separated by the 1′ angle or by .004 mm. on the retina. Stratton found that if two vertical lines placed one above the other were brought together at their extremities, a break in the line could be noted when they were displaced 7″ only. In this case, however, the difference in direction of the lines probably also gives a cue; it is not merely appreciation of the distance between points. As the distance that separates the centers of cones in the fovea is only about 40″-60″, it would seem that stimuli no farther apart than the centers of neighboring cones can be discriminated. As one proceeds outward from the fovea, the acuity diminishes very rapidly. Five degrees from the center it has been reduced to one fourth and at forty degrees to one two-hundredth of the maximum value. In twilight vision, where the cones are not involved, acuity is

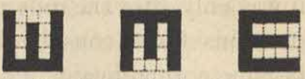

FIG. 89. — Snellen types.

approximately the same in all portions of the field beyond ten degrees from the center. It is zero in the fovea itself, and rises very rapidly to attain a constant value five to ten degrees distant.

The theories of the appreciation of position and extent upon the retina involve the same principles as those advanced for the skin. The awareness of position seems to depend in some way upon the nerve element stimulated, as is evidenced by the fact that when a retinal element is displaced it still gives the old sign of position. Thus Wundt at one time suffered from choroiditis under one small portion of the retina. This caused a swelling of the retina and finally resulted in a small scotoma or blind spot. While the elements of the retina were displaced in this region, the straight lines seen on it were distorted, and it was only after the rods and cones had been used in their new positions for a considerable time that the spatial relations became normal again.

Theories of Localization. — The sign of position that attaches to the retinal element has been ascribed to the conjectural 'local sign' and to movement. Differences in the qualities of sensations received on different areas of the retina have been suggested as furnishing the means of distinguishing position. Even the difference in the quality of a color has been mentioned as constituting the sign of position. The movement theory assumes that the tendency of the eye to turn in such a way that the point attended to shall fall upon the fovea constitutes the mark of position. The more general and inclusive the final explanation, the greater the likelihood that it will be correct. It is probable that the idea of position here, too, is a type that has been gradually developed through experience of all possible sorts, that it includes reference to motion, to areas as known on the skin, and particularly to the movement of the fingers over surfaces as eye and finger explore them together, and a large number of more general practical tests.

After the type has developed, some peculiarity in the retinal element stimulated or the activities aroused by the stimulation suggest this idea or concept. Again we have the alternative of regarding the appreciation of position as immediate. We might say that the Gestalt is an original endowment that is aroused by the stimulation of a point on the retina.

The perception of greater visual extents depends very largely upon the eye-movements. This phase of perception has been investigated with more care for the eye than for the skin. Studies in the comparison of two lines show that the appreciation of distance follows Weber's law, — one can appreciate an addition in length of from $\frac{1}{40}$ to $\frac{1}{60}$ to a horizontal line, an average of about $\frac{1}{50}$. Appreciation of difference in the length of vertical lines is slightly less accurate, an average of about $\frac{1}{40}$. This slighter degree of accuracy in perception of vertical movements has been connected with the fact that the vertical movements require two pairs of muscles and so a greater amount of effort than horizontal movements. The vertical movements are thus less accurate and more difficult to compare. As one estimates the length of a line, the eyes move from one end to the other and the comparison is probably very largely through these movements. The qualitative characteristics or group of 'local signs' may also be involved; but here, as in the liminal values, they have not been clearly discriminated.

The Eye Muscles. — The importance of eye-movement in the perception of space makes it desirable to give a brief statement of the muscular mechanism. The eye is moved by six muscles arranged in pairs, and named, from functions and attachments, the internal and external recti, the inferior and superior recti, and the inferior and superior oblique. The recti muscles all spring from near the apex of the eye socket and pass directly forward to their point of attachment on the surface of the eyeball. The superior oblique also originates at the apex but runs forward to a ring of cartilage on the upper nasal rim of the socket and then turns backward to be attached behind the center of the upper surface of the eyeball. The inferior oblique springs from the lower nasal rim of the socket and passes back to a point behind the middle of the lower surface. From the fact that the oblique muscles exert their pull toward the front, they turn the eyes in the direction opposed to their names. The direction in which the muscles turn the eyeball may be best indicated by the diagram taken from Hering. It will be seen that the internal and external recti muscles turn the eye in an approximately straight line; all the others turn it along a curve and if the eye is to be moved directly up or directly down, two muscles must coöperate (Fig. 90).

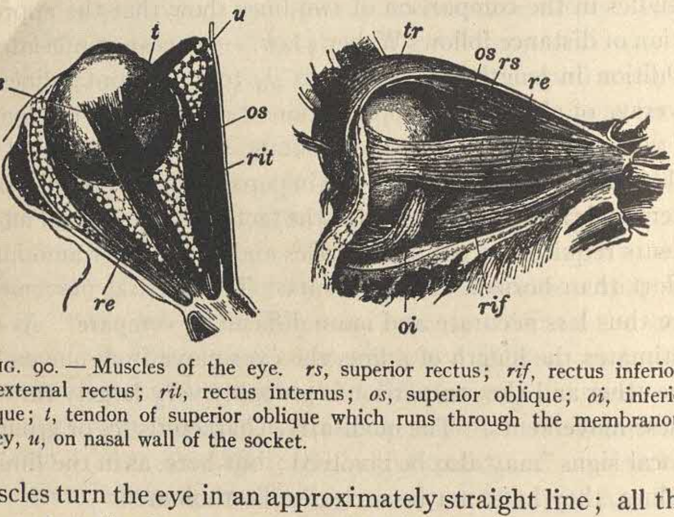

FIG. 90. — Muscles of the eye. *rs*, superior rectus; *rif*, rectus inferior; *re*, external rectus; *rit*, rectus internus; *os*, superior oblique; *oi*, inferior oblique; *t*, tendon of superior oblique which runs through the membranous pulley, *u*, on nasal wall of the socket.

Eye-Movements. — The eyeball turns around a point about 1.3 mm. behind the center of the eye. The center of rotation is 13.5 mm. back of the cornea. It should not be assumed that this point is absolutely fixed, — owing to the loose way in which the eyeball is held in its socket, it is slightly displaced as it turns, and the center of rotation moves with it. Also as the eyeball turns, it is rotated more or less about its optic axis.

This is called torsion. The amount of torsion increases with the amount of the movement, but is usually present even for slight movements. Both eyes always move together. A single impulse is sent simultaneously to the same muscles of both eyes. It is as if they were a team of horses turned by a single pull on a pair of reins. These movements follow the direction of attention, as was said in an earlier chapter. The only conscious antecedent is that some object in the field of vision shall catch the observer, then the eye muscles immediately contract in a way to bring both eyes to fixate the object. As points of reference for eye-movements, one may distinguish certain positions. What is known as the primary position is that which the eyes have when fixed on a distant object in the

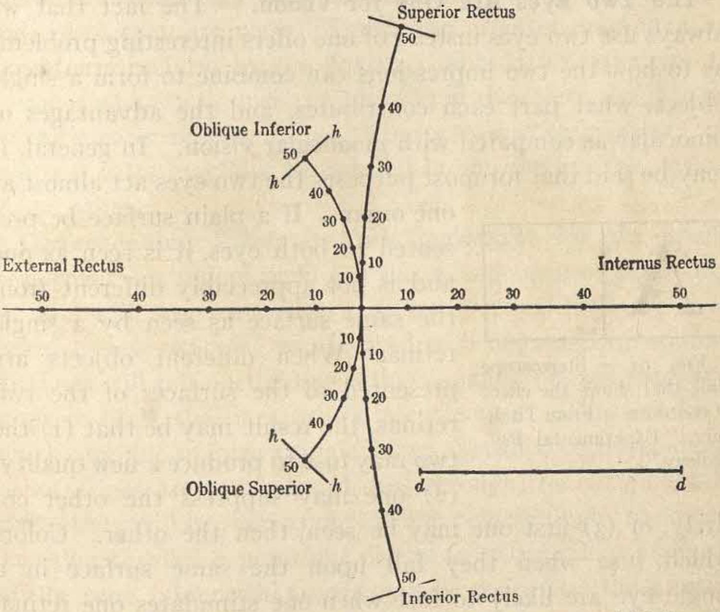

FIG. 91. — Hering's diagram to show the course the eye would follow if pulled by each muscle singly. The line *dd* indicates the distance of the eye from the page as it is moved.

median plane and a little (15°) below the horizontal. From this, movements may be made in any direction with the optic axes parallel, or the eyes may be converged upon points in the median plane or to one side of it. These positions have been called secondary and tertiary, but no agreement as to which are to be called secondary and which tertiary has been attained.

The Two Eyes Are One for Vision. — The fact that we always use two eyes instead of one offers interesting problems as to how the two impressions can combine to form a single object, what part each contributes, and the advantages of binocular as compared with monocular vision. In general, it may be said that for most purposes the two eyes act almost as one organ. If a plain surface be presented to both eyes, it is seen as one and is not appreciably different from the same surface as seen by a single retina. When different objects are presented to the surfaces of the two retinas, the result may be that (1) the two may fuse to produce a new quality, (2) one may suppress the other entirely, or (3) first one may be seen, then the other. Colors which fuse when they fall upon the same surface in a single eye are likely to fuse when one stimulates one retina, the other the other. For certain individuals there may be an alternation. Thus, if one half of a stereoscopic slide be red and the other blue, when looked at in the stereoscope they will ordinarily give a purple, but at times and in part of the field an individual will see first the red and then the blue. Where contours of any kind are presented to one eye and a uniform surface to the other, as in Figure 92, the contours will be noticed and the plain surface neglected. The law may be formulated in the statement that you see what means most to you, what is most interesting, while

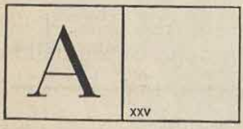

FIG. 92. — Stereoscope slide that shows the effect of contours. (From Titchener, "Experimental Psychology.")

you neglect the unimportant plain surface. Where two colors or grays, alike except in brightness, are combined, the the result is a single color with a brightness intermediate between that of the components. The brightness is usually a little greater than the average for the two stimuli. Thus, when the two are of the same brightness, the brightness of the combined image may be $\frac{1}{10}$ greater than that of either alone, and when they are very different, the brighter may have its brightness reduced by the darker. This latter is known as Fechner's paradox, since the addition of the fainter brightness to the greater reduces rather than increases the brighter. A contrast color may also be induced in one eye by stimulation of the other.

Corresponding Points. — Very important for the space problems is an understanding of the arrangement of the points or lines that are seen singly. If two vertical lines are held before the eyes and the eyes focused on a distant point so that the lines will fall on the two retinas equally distant from the fovea in each, the lines will be seen as one. Points or lines which combine to form a single image are called corresponding. If both lines are vertical and pass through the center of the fovea, they will be seen as one; if one pass through the fovea, the other through a point one degree to either side of it, both will be seen. Identical points may be defined as those equidistant from the fovea and in the same direction from it. If the two retinas could be placed one over the other in such a way that the foveas and the vertical and horizontal axes coincided, then all points that were superimposed would be identical points. Stated in terms of rays of light, those rays fall upon identical points which make the same angle and in the same direction with the lines of sight of each eye. The line of sight is the line from the fixation point to the center of the fovea. Corresponding points are those points which in practice combine to give a single image. Identical points are defined geometrically. Ordinarily they agree for practical purposes. An exception occurs when a child squints badly from birth through asymmetrical adjustment of the eye muscles. Then the fovea in one eye corresponds to a point to one side in the other. If this position is held constant, the child may see singly when an object falls on the fovea in one eye, and upon a point several degrees from the fovea in the other. Identical points would then not be corresponding. If the eyes are straightened by an operation the two foveas will learn to combine to give a single image. The identical points will then again be corresponding.

A most important problem for the perception of space is to determine how much two stimuli may depart from correspondence before they can be seen as two; or, in terms of our first problem, how far the two lines on the stereoscopic slide may depart from correspondence before they will seem to be two. Pulfrich[1] and Bourdon[2] found that two objects need have no greater deviation from correspondence than from 5″ to 12″ for the deviation to be noticed. This is considerably less than the 'limen of two-ness' for a single eye. It should be added that the lines are not necessarily seen as two, but the divergence may be translated into depth, as will be seen in a later discussion. Considerably greater deviations from correspondence may take place without being noticed if the lines are horizontal than if they are vertical.

Why two points should thus give rise to but a single image is not easy to say. The first theory, suggested by Johannes Müller, was that it was due to the fact that corresponding points were connected with the same half of the brain. It is a fact that the right half of each retina is connected with the right hemisphere, and each left half with the left hemisphere. There is, as the diagram (p. 54) shows, only a partial crossing at the chiasma, — half of the fibers cross and half go uncrossed to the same side of the brain. Müller assumed that these fibers in some way combine in the cortex, perhaps connect with the same cells, and so give rise to a single image. This would be the nativistic explanation; the combination would be due to the innate nervous connections. The empiricist, however, can cite numerous cases in which this correspondence is changed by experience. As has been said, individuals whose eyes are badly crossed, who squint, develop a new set of corresponding points; the points that have been used in seeing the same object come to give single images, or else the image from one eye is disregarded. Similarly, horizontal lines may be a considerably greater distance apart than vertical ones and still correspond. Under those circumstances experience makes it more likely that there is one line than two. If the lines be vertical and deviate very slightly from correspondence, they will be seen as two. We shall see that this deviation from correspondence of vertical lines is an important factor in the appreciation of distance, and is therefore noticed; while the necessity for distinguishing horizontal lines is relatively slight. The empiricist's explanation would be that we see the two images as one, because tests by touch or other senses have shown that there is only one object present in spite of the two images; we have learned that two images mean one object, and the positions that are most frequently stimulated together by a single object become corresponding points.

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[1] *Physikalische Zeitschrift*, no. 9, 1899.

[2] *Revue Philosophique*, vol. 25, p. 74.

The Horopter. — The problems of binocular vision and corresponding points are of interest because of the light that they throw upon the positions that objects in space must occupy if they are to be seen singly. When the eyes are converged in a given position, there is only one distance from which rays of light can fall upon corresponding points. The distance varies as convergence varies, but the locus of points in space which will send rays to corresponding points is strictly limited. Points nearer or more remote will fall upon non-corresponding points and so give double images. The locus

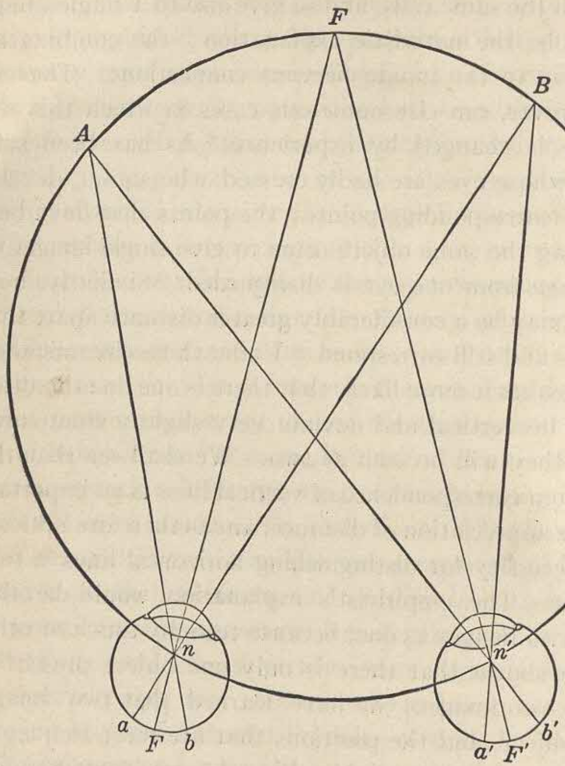

FIG. 93. — Müller's Horopter Circle. *a* and *a'*, *b* and *b'* are corresponding points. Lines drawn from these points through the nodal point will meet in a circle that passes through the fixation point *F* and through the two nodal points, *n* and *n'*, at *A* and *B*.

of all points that fall upon corresponding points is called the horopter. The form of the horopter has been developed mathematically in great detail. Two forms of the horopter may be mentioned. When the eyes are converged upon a point in the plane halfway between them, the horopter is a circle passing through the fixation point and the nodal points of both eyes. To this is added a vertical line through the fixation point. When the eyes are parallel, all points at an infinite distance, the distance at which parallel lines meet, would fall in the horopter, theoretically. In practice, the horopter is composed of all space beyond the point where the departure from the parallel is less than 5″, the least disparateness that can be appreciated, or beyond a distance of some 2500 meters.

The Perception of Depth. — Many of the facts which have been mentioned up to this point are involved in an explanation of how we appreciate the distance of objects away from us, what is often called depth or the third dimension. The third dimension differs from the other two in that the factors which make possible its appreciation are indirect. There is no direct correspondence between the area of the retina stimulated and of the depth assigned to the object as is approximated in the appreciation of position and of length on skin or retina. Distance is apparently inferred rather than seen. We are accustomed to distinguish two sets of signs which give a basis for the estimation of depth. One set has a definite correlate in changes in the eye itself. These receive the name of physiological factors. The others depend upon incidental changes in the qualities of sensations with distance and are frequently called the psychological factors.

Dependence of Depth Appreciation upon Accommodation. — In the single eye the most important means of discriminating the depth of objects is the change in the ciliary muscle to adjust the lens for different distances (see p. 107). The ciliary muscle in the young eye automatically contracts or relaxes to change the shape of the lens to give a clear image. It would seem that the kinæsthetic sensations from the muscle should give a cue as to the distance of the object and this theory has been generally held since Helmholtz. Bourdon and others have given the results of experiments which seemed to indicate that when the retinal image is kept of the same size when the distance changes the observer cannot appreciate change in distance with one eye alone. Careful experiments by Mrs. Van Tuyl with an apparatus which changed the size of a slit to compensate for changes in distance found evidence that individuals can appreciate depth by the changes in the ciliary muscle. Ordinarily the observer decides that an object has changed its distance from the fact that it is out of focus. This gives no indication of the direction of the change. With practice the observer does learn to interpret the changes in the ciliary muscle to make a correct distinction between near and far. When a near object is attended to, the ciliary muscle is contracted and this permits the lens to thicken and give a clear image of the object. On the other hand, when a more distant object is attended to, the ciliary muscle is relaxed and the lens is flattened by the tension on the suspensory ligament and so adapted to receive a clear image from distant objects. The degree of strain varies inversely as the distance, and is immediately interpreted to mean the distance of the object. One thinks of objects that are seen with much strain, as near; of those that are seen without strain, as remote. (No strain is required for objects more than about 50 feet away.) As is usual in all perception, these factors are not observed in themselves; the distance alone ordinarily comes to consciousness.

Convergence as a Factor in Distance Perception. — When two eyes are used for the appreciation of distance, estimates are much more accurate than when one eye is used. If a man looks at a landscape with one eye, the objects appear much flatter than if he looks with two. Or if one attempts to put a finger through a ring held before the eye from the side, one will not succeed readily when one eye is closed, although one finds it perfectly easy when both eyes are open. Evidently new signs of distance are involved when both eyes are used. Two of these are important. One is muscular, the movements required to converge the eyes upon a single object. Distant objects are viewed with the eyes nearly parallel and with the muscles fairly completely relaxed. As an object comes nearer, it is necessary to contract the internal recti muscles that the eyes may be converged to see it with the foveas. This gives rise to another strain which also decreases with the distance. This strain is a more accurate index of distance and furthermore can be used to detect distance over a longer range than can the strain of accommodation. If one compares the distance of a thread seen at different distances first with one eye, then with both, under conditions that restrict the means of determining distance to the muscular adjustment, it is found that the distances that can be distinguished are much less in the latter case than in the former. This is shown in the table below, taken from Wundt.

TABLE II

UNIOCULAR		BINOCULAR COMPARISON	
Distance	Limen	Limen	Relative Limen
cm.	cm.	cm.	
250	12		
180	8	3.5	1/50
130		2.0	1/64
100	8		
80	5	2.0	1/39
70		1.5	1/45
60		1.0	1/50
40	4.5		

The distance is the absolute distance from the eye; the limen, the difference in distance that can be just noticed; while the relative limen is the limen for binocular vision divided by the absolute distance. This, it will be noticed, is approximately the same as the difference limen for the comparison of horizontal lines on a flat surface, in which movements have also been regarded as an important factor. The relative limina vary between $\frac{1}{39}$ and $\frac{1}{64}$ of the total distance. They average not far from $\frac{1}{50}$. This table is based on results which did not eliminate the apparent size of the object and other factors. It does give a good notion of the relation of monocular to binocular estimation of depth under the conditions of everyday life.

Double Images in the Perception of Distance. — Still another indication of the distance of objects is given by the differences in the images of the objects on the two retinas. One may be said to get a different image of a distance with each eye. If one hold a ruler end on in front of the eyes and close first one eye and then the other, it will be noted that the image shifts as the eyes are changed. If one converges upon the far end, with both eyes open, the near end will be seen double, while if one looks at the nearer end, the farther will be double. In either case the image of the ruler will slant from the double to the single end. These double images will not be noticed at first but will be used as immediate signs of the distance of one end from the other. Similarly, if two threads are present simultaneously in the field of vision at different distances, the one fixated will be seen single, the other double, and the elements of the double image will be separated by a space that increases with the distance between the threads. This doubleness is of value only in determining the distance between two objects or points, not for the determination of the absolute distance of a single object. The degree of doubleness changes with each position of the eyes as well as with the distance of the object. Given the absolute distance of any point of reference, the distance of any other point from that in the field of vision may be determined.

Not only may the observer estimate the distance between two threads in this way, but he can determine which is nearer and which farther. If one fixate the more remote, the double images are crossed; that is, the one on the right is seen with the left eye, and *vice versa*. If one fixate the nearer, the more remote gives uncrossed double images. This can be tested by closing one eye. It will be noticed that when the farther object is looked at and one eye is closed, the image on the

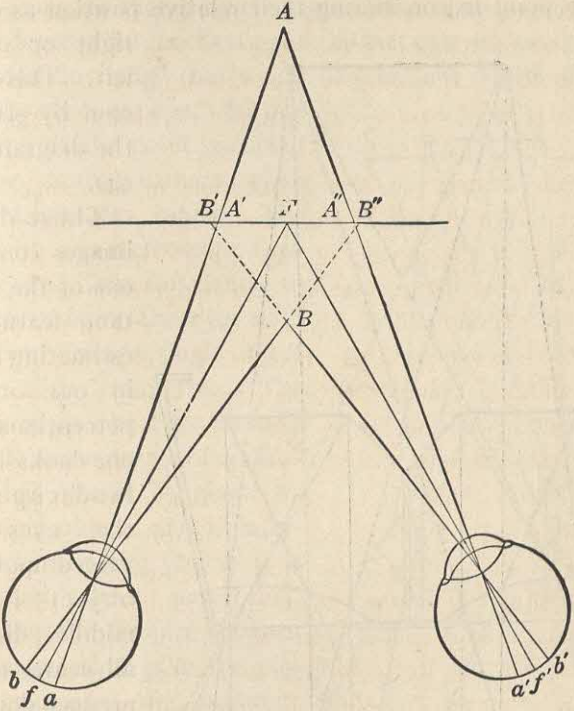

FIG. 94. — To illustrate crossed and uncrossed images. F is the fixation point and is seen singly. An image of a more distant point A falls upon points a and a' on the retinas, which are non-corresponding. As excitations of the retina are projected to the plane of the fixation point, they are seen at A' and A'' and are therefore uncrossed, the image seen with the right eye is seen to the right of the fixation point and to the right of the image seen with the left eye. Objects nearer than the fixation point, as B, will also be projected to the fixation plane at B' and B'' and so are crossed, the image on the right retina is seen as if it were to the left of the fixation point and *vice versa*.

same side disappears; when the nearer object is fixated, the image on the opposite side disappears. This occurs because the double images are always referred to the plane of the fixation point in considering their relative position as on the right or on the left. This can be seen by study of the diagram (Fig. 94).

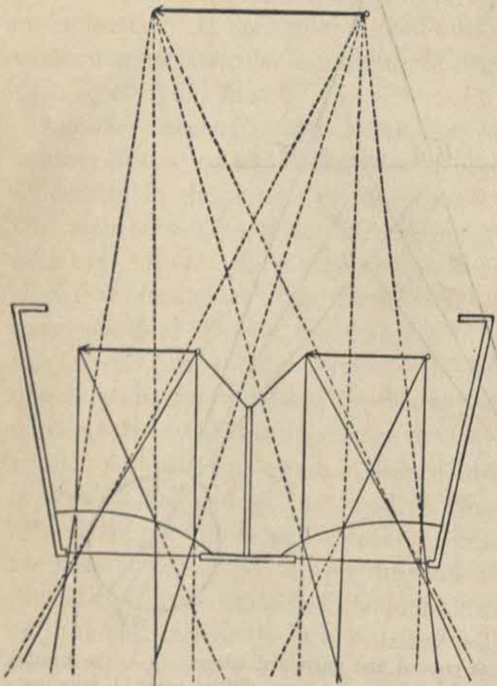

FIG. 95. — Diagram of prism stereoscope. (From Titchener, "Experimental Psychology.")

These double images constitute one of the important features in estimating depth in our ordinary perceptions. As one looks at any landscape with the eyes converged upon some object in the middle distance, all nearer objects are seen double in crossed images; all more remote objects are seen double in uncrossed images, and the degree of doubleness increases with the distance from the object fixated. These double images are not ordinarily seen for themselves, but are at once translated into distance, just as are the strains of accommodation and convergence. However, they can be noticed with a little practice. So close has become the association between double images and the perception of distance that when letters are printed to appear double, they seem nearer or farther even when viewed with a single eye. The importance of the double images may be shown by the use of the ordinary stereoscope which depends for its effect upon the fact that the two pictures represent the image that would be seen, one by the left, the other by the right eye, were one standing at the point occupied by the double camera when the picture was taken. The prisms in the stereoscope turn the rays of light sufficiently to have them enter the eyes as if they came from a single object rather than from two. The difference in the two pictures gives the same degree of doubleness that would be given by the single object, and is interpreted as distance just as it is in actual space perception. Increasing the distance between the cameras that take the pictures, increases the apparent depth.

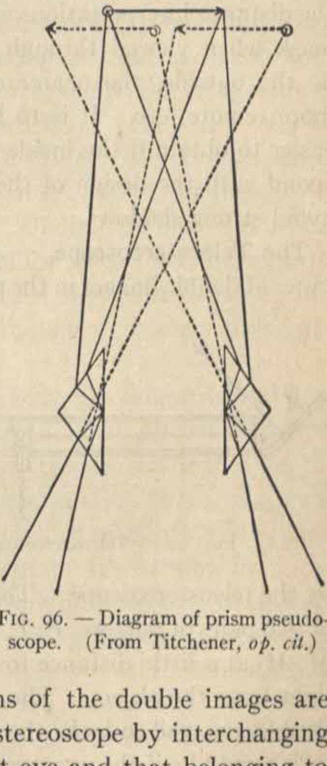

FIG. 96. — Diagram of prism pseudoscope. (From Titchener, *op. cit.*)

The Pseudoscope. — Even more striking is the effect of the pseudoscope. If the relations of the double images are reversed, as may be done in the stereoscope by interchanging the picture belonging to the right eye and that belonging to the left, the nearer objects appear farther away, the more distant nearer than the point of fixation. The same effect may be obtained with real objects by using the pseudoscope devised by Wheatstone. This consists of two right-angle prisms mounted in tubes that can be brought one before each eye. The images are reversed in passing through the prisms, and this makes the images that come from the nearer object enter the eyes as if they came from the more remote; the character of the double images is reversed, those from objects more remote than the fixation point are crossed, those from objects nearer than the fixation point are uncrossed. In consequence, the distance interpretations are also reversed. The inside of a mask when viewed through the pseudoscope will appear to be the outside, the nearer of two threads will seem to be more remote, etc. It is to be noted that the effect is much easier to obtain if the inside of the mask be painted to correspond with the design of the outside, and is so lighted as to avoid strong shadows.

The Teleostereoscope. — Another indication of the importance of double images in the perception of distance is furnished by the teleostereoscope. This instrument consists in principle of two pairs of mirrors, *P*, *P*, one before each eye, and another, *M*, *M*, at a little distance to the outside to receive the rays of light from the object. The effect is to increase the degree of doubleness, and to make the perception of distance as accurate as it would be if the eyes were as far apart as the more widely separated mirrors that first receive the rays of light. The course of the rays may be made out from Figure 97. A similar device is used in the better field glasses at present. Surfaces of prisms supply the mirrors and these are separated

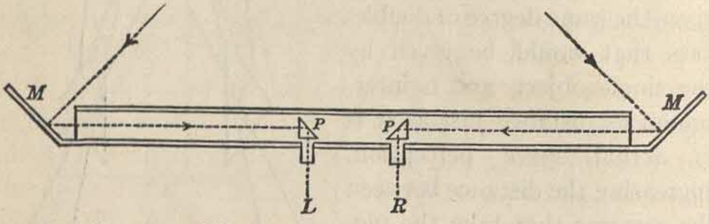

FIG. 97. — Teleostereoscope. (From Titchener, *op. cit.*)

by a much smaller distance to make the instrument more portable, but they serve to increase markedly the accuracy of the estimation of distance.

These three factors, (1) the strain of accommodating the eye to different distances, (2) the strain of converging the eyes upon an object, and (3) the double images, constitute the signs of depth that may be said to depend upon the structure of the organs, and are sometimes called the primary factors. They vary in accuracy, — accommodation is least accurate, convergence about five times as accurate, and double images much more accurate than either of the others. They also vary in the distance at which they are effective. Accommodation is an aid only for objects nearer than fifty feet; convergence is effective up to about 300 feet. Under the best conditions double images give an idea of distance up to about 2500 yards. Beyond 2500 yards, the more distant objects show no appreciable doubleness of images, although of course all nearer objects are seen as double.

It should be emphasized here as in connection with the 'local sign,' that, while experiments prove that all of these different factors are in some way necessary to appreciation of depth, they are not appreciated for themselves. What the individual is aware of is the type or Gestalt of depth. He is not aware of strains within the eye or of the strains from the external muscles of the eye or of double images. He merely sees immediately that an object is a certain distance away from him. We may believe that the 'type' or Gestalt is built up on the basis of experience or that it is immediate. However it has been derived, it is now a unitary unanalyzable experience.

The Psychological Factors in Depth Perception. — While these physiological factors make possible the most accurate estimation of depth, many other signs of distance are of great value. The others consist of changes in the character of the image as the distance changes. They are the secondary or psychological factors. Perhaps the most important of these is perspective. The size of an object is inversely proportional to the distance. If one knows the size of any object in the field of vision, it is altogether possible to infer its distance from its apparent size, the size of the image. The importance of this means of obtaining an idea of distance may be gathered from the use of perspective in art. The distance ascribed to an object in a photograph or painting depends very largely upon its size, relative to other objects in the photograph. Here, as in the other factors, the estimates of distance are not made consciously; one does not first notice the diminished size and then infer how far away the object must be to give that distance, but sees the distance at once, and corrects the size of the object in accordance with his estimate of its distance. The object seems to be of full size and at the correct distance. The tendency to overlook the difference in size is evident from the relatively late development of perspective in art. The early paintings and bas-reliefs make distant objects of the same size as the nearer ones. Obviously the early artist had not noticed the phenomenon of perspective but inferred distance without knowing how. Even now an artist often draws his distant objects larger than they should be.

A second factor under this head is the higher position of more distant objects in the field of view. Objects on a flat ground plane appear to rise gradually as they go away from the eyes and, with proper allowance for the actual height of the object above the ground plane, the relative height may be used as a measure of distance. This factor was recognized by the early artists. Their distant figures are placed higher than the nearer, an arrangement that makes it possible to show the more remote, as well as to imitate the apparent effects of distance. The haziness or distinctness of objects is also an important factor. This can be seen from the tendency to mistake distant objects for near, where the air is particularly clear. In theaters it is customary to draw a net in front of the more remote parts of the scene. The net gives the effect of haze. Distant objects appear blue. Both of these effects are due to the absorption of light waves by the air intervening between the object and the observer. The condition is sometimes called air perspective. An element almost too obvious to mention, but nevertheless highly important in practice, is superposition. The partly hidden object must be more remote than the one fully seen.

Motion an Aid to Distance Perception. — Motion, both of the observer and of the object, aids in the perception of depth. When the head is moved to one side, all objects in the field of vision are displaced in different degrees. If one is looking at an object in the middle distance, all nearer objects shift in the direction opposite to the movement, all more remote ones in the same direction as the movement. The amount of the apparent displacement increases with the distance between the object and the fixation point. When one is in rapid motion as in a railway carriage or an automobile and is looking at a point in the middle distance, there is a constant procession of the near objects backward and the more remote objects forward, at a rate that depends upon their distance and the rate of motion. This gives a notion of distance. When objects are themselves in motion, the apparent rate of motion compared with the usual rate of the object at a standard distance serves as an indication of its distance. When seen from a rapidly moving vehicle objects seem smaller than they are because they seem to be moving much more rapidly than usual. This means that they are regarded as much nearer than they really are, and this by the habits of perspective makes them seem small.

Shadows in Space Perception. — Another factor that aids in determining the form of objects in the third dimension is the interpretation put upon shadows and high lights. The nearer surfaces are usually well illuminated while the more remote are more or less in the shadow. This is translated at once into depth or distance and the shadows themselves are little noticed. Shadows are much used by the artist; in fact they are quite as important as perspective in enabling him to represent depth in the contour of an object on the flat canvas. In the real object, much depends upon the knowledge of the direction from which the light comes, or from assumptions that are made concerning the direction. If one will look at a cameo under a microscope which reverses the image, it seems to become an intaglio. The high lights fall on the side that they would were the depth relations reversed, and the depth is also reversed. In depressions made in steel by a smooth ball lighted from all

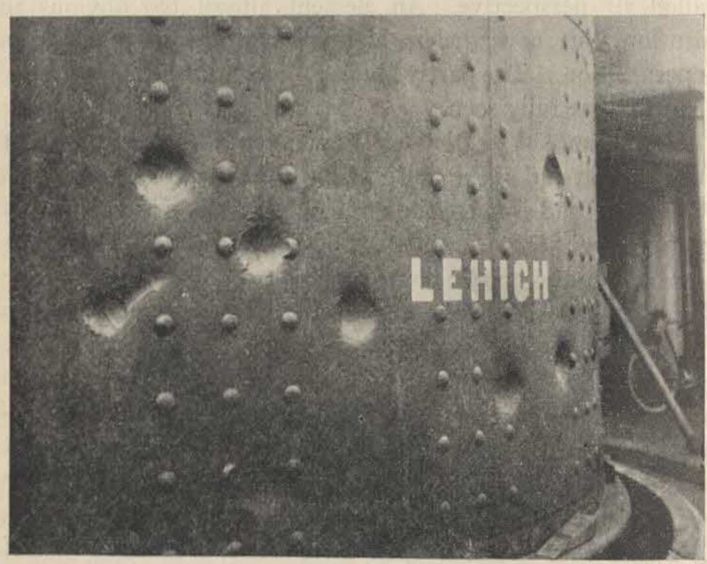

FIG. 98. — Illustrates the effects of shadows on depth perception. Invert the book and it will be seen that the depressions become protuberances, and the rivet heads depressions. (From the Stoelting Co., after Titchener.)

sides to give numerous reflections, it is quite easy to see the depression as a protuberance (Fig. 98).

Depth for vision, then, is appreciated by virtue of a number of differences in the sensations that come from the muscles of the eye, external and internal; by the double images due to the different image presented to each eye; and by a number of peculiarities of the image of an object that change with the distance. These sensations are not first seen for themselves and then associated with the idea of distance, but as a result of their presence the object is at once seen at the corresponding distance. In this respect the third dimension is, like the other two dimensions and the idea of position, apparently received immediately, and can be analyzed into its elements only indirectly.

AUDITORY SPACE

Auditory Perception of Space. — One other sort of perception of distance needs to be mentioned, the perception of the position and distance of sounds. Unlike tactual and visual sensations, there is in sound no really two-dimensional space, no perception of objects in contact with the sense organ, but merely perception of the distance and direction of objects that give rise to sounds. These localizations are relatively uncertain and indefinite. One is constantly deceived as to the distance and direction of sounds. The breathing of a dog on the hearth may be mistaken for distant thunder or some other intense but distant noise. Front and back are often confused. Right and left much less often; but still under the influence of suggestion, confusions of this sort are far from infrequent. Experiments indicate that the primary factor in the perception of distance is the intensity of the sound as compared with the sound given at some known or standard distance. This implies, first, a recognition of the source of the sound, then an association between the present intensity of the sound and the distance that would give the particular intensity. A locomotive whistle has been heard at a number of different distances, more or less accurately observed or measured. When it is recognized, its intensity at once suggests the distance. This is true of any familiar sound. If the sound be altogether unfamiliar, appreciation of distance is difficult, although if it be recognized as belonging to some known class, an estimate can usually be made.

The Appreciation of the Direction of Sounds. — Estimation of the direction from which a sound comes depends upon a number of different sensory data. Longest known and most obvious is the relative intensity of the sound as heard by the two ears. The sound is loudest in the ear turned towards the source of sound. A second factor is that the two ears hear the sound at slightly different times when a single click is given. The ear turned towards the click hears it a fraction of a second earlier than does the other. Closely related to this is the difference in phase of a continuing tone. This increase in the time required to stimulate the ear turned away causes a persisting tone to be heard in a slightly different phase by each ear. Thus, if the difference in distance were half a double vibration, in length, the tone on the nearer ear would be pulling the drum out while that on the farther ear was pushing the drum in. Usually the difference in phase would not be so great, but is always appreciable. Stewart and others have proven that if a telephone be attached to each ear and by controlling the phase electrically, a tone of the same pitch, but in a different phase be presented to each ear, there will seem to be a single tone and the localization of the tone will vary as the phase is changed. Von Hornbostel[1] has convinced himself that the relative time of beginning the stimulation of the ears is the only really important factor in determining the direction of a tone. More facts are needed before we can assign relative importance to the three criteria that have been suggested.

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[1] *Handbuch der normalen u. patholog. Physiologie*, vol. xi, pt. 1, p. 612.

Distinguishing sounds which come from in front from those which come from behind offers greater difficulties. With pure tones it is almost impossible. If two tuning forks of the same pitch be vibrating, one directly in front, the other directly behind, and one be stopped, it is almost impossible to tell which is still sounding. The percentage of mistakes will approach fifty. If the sounds be complex, are noises, or from instruments rich in overtones, fewer mistakes are made. This suggests that the quality of the tone is in some way modified by the direction from which the tone comes. Angell asserts that this may be due to the way in which the various overtones are modified when the tone strikes the outer ear. From one direction, one overtone or group of overtones will be reënforced, from another direction another will be strengthened, and the resulting complex tones enable one to determine the direction. Myers[1] has shown experimentally that changes in the timbre of a tone will induce changes in localization. If a tone be sounded directly in front until the observer has acquired practice in localizing, and then the component parts of the tone be changed to give it a different quality, the sound, although still coming from in front, will be localized in some other position. Myers found, too, that when he placed short rubber tubes in the ears, all capacity for determining the position of sounds disappeared. These tubes made it impossible for the external ear to modify the quality of the tones or their intensity. Changes in the intensity of the sound also induce similar mistakes. The importance of the changed intensities is to be related to the fact that sounds from in front are caught by the pinna, the outer ear, and focused into the meatus, while sounds from behind are diminished in volume. When the absolute intensity and the distance of a sound are known or may be approximated, the position of the sound as in front of or behind the plane of the ears can be appreciated in terms of intensity. Direction of sounds, then, is appreciated by means of the relative intensities of the tones as heard by the two ears; by the difference in time of starting the stimulation of the two ears; and by the difference in phase in the two ears. The timbre and intensity of the tone are also important. It has at times been assumed that direction might be known by means of the stimulation of the skin in the neighborhood of the ears, or on other portions of the face. This assumption is improbable in itself, since sound waves are not sufficiently intense to excite the organs of pressure.

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[1] C. S. Myers, *Proc. Royal Society*, B., vol. 88, pp. 267–284, 1914.

The Auditory Space of the Blind. — Auditory appreciation of space plays a much larger part for the blind, who must trust to the ears for a knowledge of the position of all distant objects. A blind man appreciates the distance of objects fairly accurately through the effect they have upon the quality of familiar sounds, such as his footsteps or the tapping of his cane. Large objects reflect the sound, give echoes, or modify its quality. It is easy to distinguish the difference in the voice when speaking in a room filled with people and when speaking in an empty room. Even the presence of furniture in a room in an ordinary dwelling has a pronounced effect. The blind man learns to distinguish all of these differences and to learn what they mean as to the presence and arrangement of objects. That the blind depend upon the reflection of sounds in avoiding objects was shown by Dr. Heller,[1] director of a blind asylum, who on one occasion provided his pupils with felt slippers in place of their heavy shoes and watched them at their play. He found that they no longer avoided obstacles and would come into conflict with many of them. The sound from their footsteps could no longer be heard sufficiently for the modifications by the obstacles to be noticed. It seems, then, that for the blind much of the perception of space depends upon the modification of the sounds of the footsteps and of other familiar sounds, by walls and objects in general.

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[1] T. Heller, *Studien zur blinden Psychologie*, 1904, Leipzig.

ILLUSIONS IN SPACE PERCEPTION

Optical Illusions. — Very important in demonstrating different factors that give rise to the appreciation of space are the so-called optical illusions. An illusion in general is a perception which proves on test not to correspond to reality. We frequently couple illusions and hallucinations. They are both misinterpretations of objects. They differ, however, in so far as in illusion there is a sensation presented which is merely distorted in some way; in hallucinations, no sensations can be readily detected. The fancied object is centrally aroused, as when a man in delirium tremens sees a mouse running up the wall. Optical illusions take many forms. They may be grouped into illusions of extent, in which length of line or size of figures is affected; illusions of the size of angles, and the related illusions of direction. The theories that have been advanced to explain the different illusions are very numerous and constantly increasing. A few are applicable in different degree to most of the illusions. These are advanced in several cases in advocacy of a general theory. Others are restricted to one illusion or to a group of illusions. All are interesting in showing the varied nature of theories of space.

Illusions of Length. — One of the simplest illusions of length is that a vertical line seems longer than a horizontal of the same objective length. Figure 99, *A* and *D*, gives pure illustrations of this. Two explanations have been frequently given for the overestimation of vertical lines. One, suggested by Wundt, is that it is determined by appreciation of eye-movement. The assumption is that the eyes move along the lines, and the distance traveled is appreciated by the sensations from the eye muscles. Only one strong muscle is required to move the eyes from right to left, while weaker ones are involved in moving it up or down. It is argued that more strain would be produced when the eye moves up than when it moves on a horizontal line. The greater strain is supposed to be interpreted as a greater length. Similarly one overestimates the upper half of the field as compared with the lower. This can be seen in the fact that a figure 8 or an *H* has the dividing line above the middle and still seems to be approximately evenly divided. When one of these is inverted the difference is markedly increased. This again is explained by the fact that the superior rectus and the inferior oblique muscle which turn the eyes up are weaker than the inferior rectus and superior oblique which turn them down. Helmholtz suggested that the overestimation of the vertical was due to a habit derived from the use of perspective. Vertical lines in space, as in a picture, usually or frequently represent greater horizontal distances seen in perspective, and so we form the habit of overestimating all vertical lines.

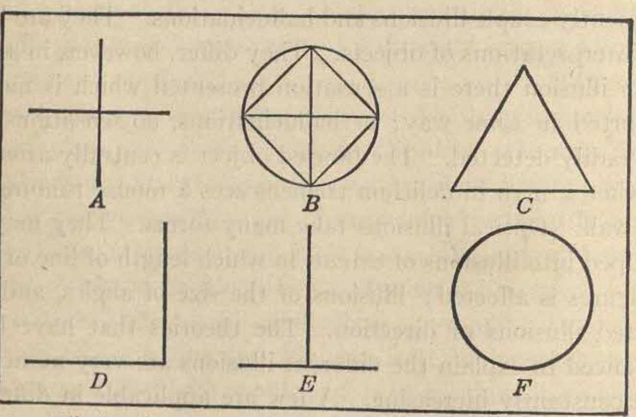


FIG. 99. — Illusions due to overestimation of the vertical. (From Titchener, *op. cit.*)

Filled Spaces Overestimated. — Another very familiar illusion is that spaces that are interrupted by dots seem longer than empty spaces. A number of these are brought together in Figure 100. According to one theory the interrupted spaces are made to seem longer by a similar exaggeration of the apparent movements through the numerous stops that are made at each of the intervening dots or lines. That this is not the whole story can be seen from the fact that where the dots are

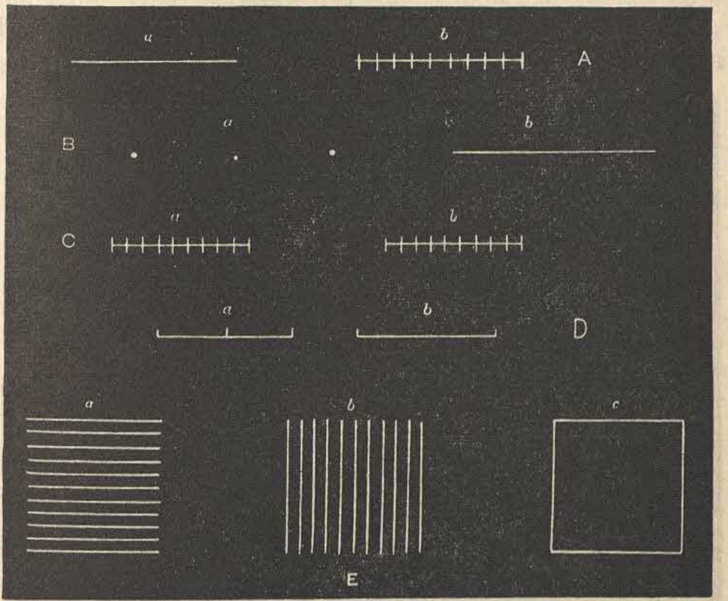


FIG. 100. — Illusions of empty and filled space. (From Titchener.)

relatively few (Fig. 100, *D*), one or two only in the length of the line, the distance is underestimated rather than overestimated. The other explanation is that the filled spaces give an impression of multiplicity and this is confused with the length of the line. The apparent shortening of the line when only one or two dots are inserted is seemingly due to a confusion between the separate spaces and the total length. The full line tends to be compared with the smaller divisions of the divided line. This same confusion is better illustrated in the comparison of the vertical and the horizontal lines in Figure 99, *E*. Here the vertical is compared with the halves of the base line. Where erected at the end of the line, the vertical is slightly overestimated but relatively very slightly (Fig. 99, *D*). This effect can be eliminated by turning the book ninety degrees, while the illusion in *E* persists.

The Müller-Lyer Illusion. — One of the most striking and most discussed of all is the Müller-Lyer illusion. It will be noted that the line, bounded by oblique lines that turn in, seems much shorter than the other line of the same length bounded by oblique lines that turn out. The explanations offered for this illusion include practically all that may be offered for any. Wundt suggested that it was due to eye-movements, that the eyes were checked too soon by the lines that turn in, and carried on by the lines that turn out. Thiery suggested that it can be explained on the basis of perspective;

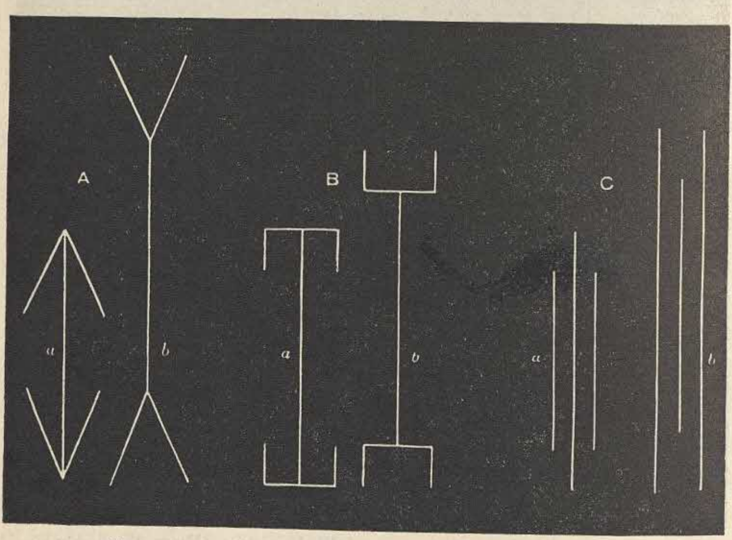
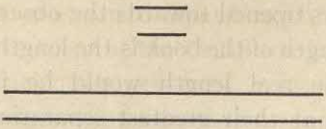


FIG. 101. — Various forms of the Müller-Lyer illusion.

that one represents an open book or similar figure with the back towards the observer, the other an open book, much larger, with covers opened towards the observer. In the first case the actual length of the book is the length of the line itself; in the other, the real length would be from the end of the oblique lines at their greatest separation. Still another theory is that one confuses the whole spaces between the oblique lines with the horizontal lines and really makes a judgment of the spaces, although it is assumed that the lines are being compared. This is one application of the so-called theory of confluxion and contrast. It is an instance of the confluxion phase of the theory. The parts of the figure tend to flow into the surrounding figures or parts of figures and be confused with them.

The eye-movement theory is in this case rather far-fetched. Dawes-Hicks found that the illusion persisted when the figures were exposed for too short a time to permit the eyes to move. And while Judd found that moving pictures taken of the eyes while the figures are being compared showed movements that in many instances correspond to the illusion, he concluded that the movements are due to the illusion rather than the illusion due to the movement. The perspective theory serves to correlate a number of different illusions, and perspective may have some influence, but it is hardly to be regarded as the only explanation. In a wide sense, the confluxion theory comes to mean that factors, other than those immediately compared, have a part in determining the comparison, and in this form, it would include the perspective element as well as any other considerations which might aid in controlling the judgment. On the whole it more nearly corresponds to the facts.

Illusions of size that illustrate the effect of contrast are seen in the lines of Figure 102 and the circles of Figure 103. The distance between two short lines seems much longer than one of the same length between two long lines. Much the same effect is obtained with the circles. In Figure 104, when the two circles are put together to form a band, the one seems larger,



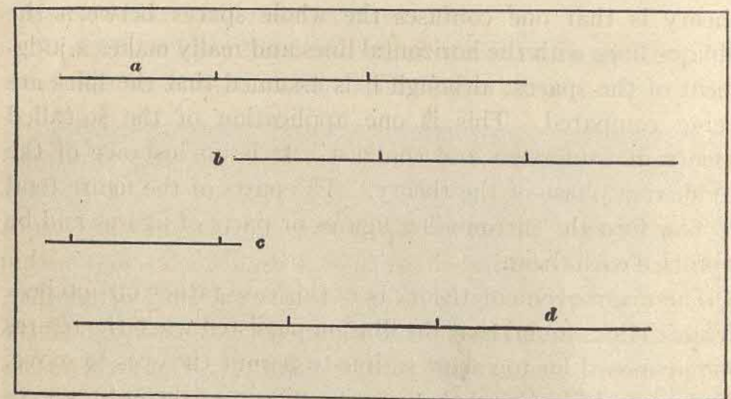


FIG. 102. — Contrast illusions. (From Titchener, *op. cit.*)

the other smaller, than when separate. When together, the observer confuses each with the center of the ring, and so tends

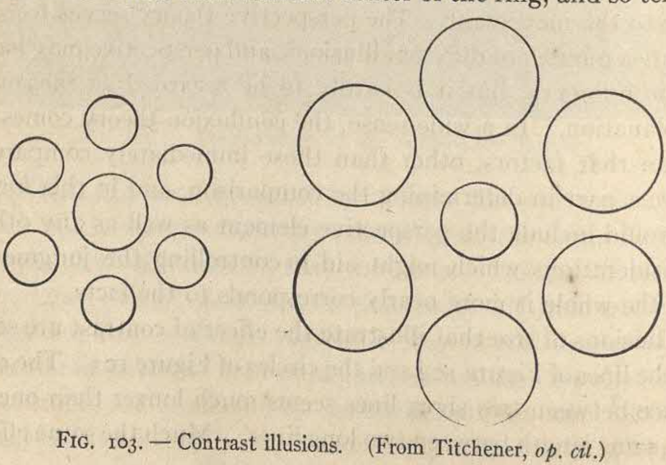


FIG. 103. — Contrast illusions. (From Titchener, *op. cit.*)

to judge each as of the size of a circle half way between them (confluxion). When a circle is surrounded by a series of very small circles, its size seems to increase as compared with

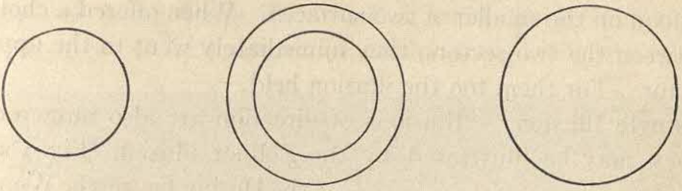


FIG. 104. — Illusion due to confluxion. (From Titchener, *op. cit.*)

the same circle near a single much larger one (contrast) (Fig. 103).

The Gestalt Theory of Illusions. — In general the Gestalt theory explains optical illusions as a result of tensions within the figures involved that would distort one part or another. Thus the square in the circle of Figure 99, *B*, is said to draw the circle towards itself at the points of contact. The circle pushes the lines of the square away from it and so bends it. The apparent increase of the smaller circle and the decrease in the larger one in Figure 104, when they are combined to form the middle ring is said to be due to the mutual attraction of the circles for each other. Similar attraction between the stimuli are said in general to account for the other illusions, although the principle has been applied most definitely to these two.

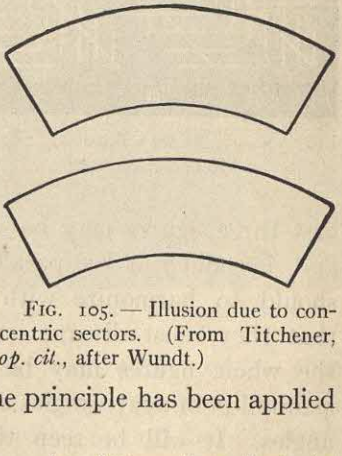


FIG. 105. — Illusion due to concentric sectors. (From Titchener, *op. cit.*, after Wundt.)

Revesz Illusion with Chicks. — An interesting fact in connection with the illusion of concentric sectors was one that Revesz demonstrated to hold for chicks. The illusion is shown in Figure 105. The upper sector is of the same size as the lower. It seems considerably smaller, probably from the habit of expecting the boundaries to extend to the radii that bound the lower sector. Revesz had trained chicks to peck at food on the smaller of two surfaces. When offered a choice between the two sectors, they immediately went to the upper sector. For them too the illusion held.

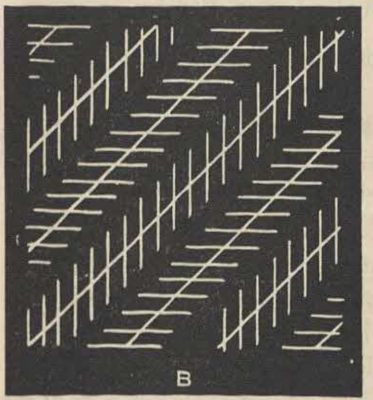


FIG. 106. — Zöllner's illusion. (From Titchener, *op. cit.*)

Angle Illusion. — Illusions of direction are also numerous. They may be illustrated by the Zöllner illusion (Fig. 106), the Hering figure, the Wundt figure (Fig. 107, *A* and *B*), and the Poggendorf figure (Fig. 108). The eye-movement theory, the perspective explanation, and confluxion have all been used as explanations. The eye-movement theory holds that the eyes are distracted by the cross lines; but why they should be is not made particularly clear. The perspective theory may take two forms. Each of the first three figures may be seen as if drawn in perspective; and, inasmuch as the parallel lines do not converge as they should to harmonize with the perspective, it is assumed that they must diverge. Still another application is that the whole figures may be explained as due to the overestimation of acute angles and the underestimation of obtuse angles. It will be seen that this is what really happens in each case. But it may be said, in addition, that the estimation of the angles is made on the assumption that whenever two lines cross at right angles and are distorted by perspective, the figure represents two lines crossing at right angles as seen with the horizontal line in an oblique plane. This can be made out in Figures 109 and 110, where the two lines can easily be imagined to represent two lines crossing at right angles. Since all angles made by straight lines are likely to indicate right angles seen in perspective, we have acquired the habit of overestimating acute and underestimating obtuse angles. The Poggendorf illusion readily falls under this explanation. The lines do not meet, because each is turned toward the horizontal; and they are turned toward the horizontal by the overestimation of the small angles; or to go back to the explanation of that tendency, one inclines to see it as if it were really more nearly perpendicular to the vertical line.

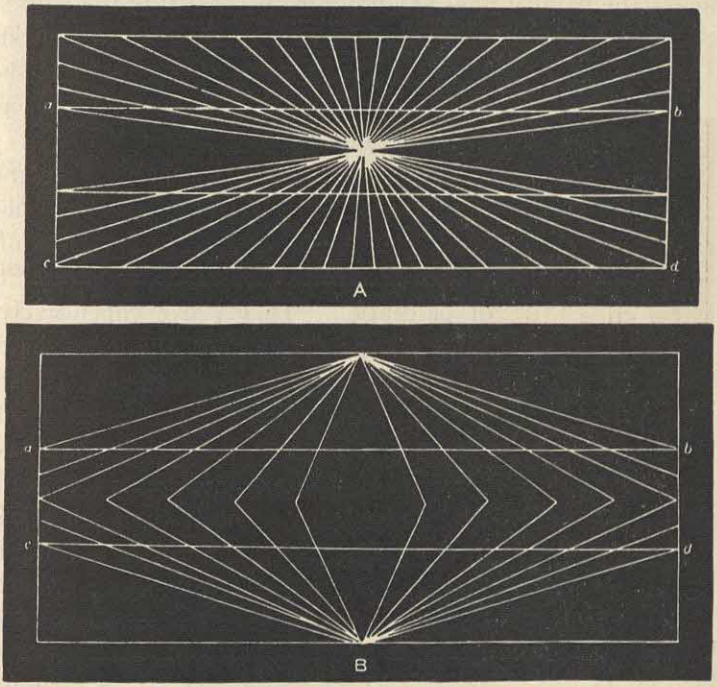


FIG. 107. — Hering's and Wundt's figures. (From Titchener, *op. cit.*)

Koffka's Gestalt interpretation of the angle illusions, of the Poggendorf illusion in particular, is that the whole figure determines the interpretation of the parts. In the angles the lines at the small angles tend to be drawn in by the cohesive strains of the figure as a whole. In the Wundt and Hering figures the parallel lines are assumed to constitute the figure, and the oblique lines the ground against which they are seen. The ground tends to be confused with the figure and hence draws it to itself.

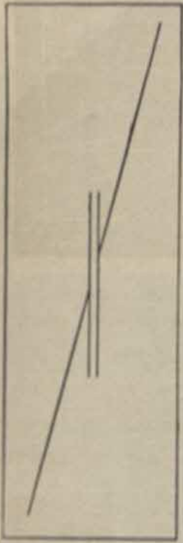


FIG. 108. — Poggendorf's illusion. (From Titchener, *op. cit.*)

Illusions in general, whatever interpretation of them be accepted, offer convincing evidence of the great variety of factors that coöperate in the development of perception. They prove conclusively that perceptions are not the immediate products of stimulation of the sense organs. Old memories and generalized habits of response are as important as sensation in determining what is seen, and frequently prove stronger than sensation in deciding which shall win in a contest for dominating the interpretation. Many of these become generalized into concepts or types, and the type replaces sensation. If one prefer to speak in terms of Gestalt, the Gestalt as a whole with its inherent tensions dominates the parts, even to prevent the true interpretation.

General Theories of Space Perception. — A more abstract problem naturally arises at the end of a statement of the particular facts of space perception, — the question, what is the idea of space itself. Two schools have contended over this question since the beginnings of modern philosophy. One, the nativistic school, insists that the capacity to appreciate space is born with us, and may be used without preliminary practice. It may be dependent upon inherited characteristics of our nervous system, or may be an original mental activity. The other school, the empirical, asserts that the notion of space is developed through experience, — must be derived in some way from the conditions of perception. For the nativist, space offers no problems; it is appreciated at once, as color is appreciated. For the empiricist, it is necessary to discover the components of the space idea and also to determine how a particular space idea is suggested. No good concrete evidence for either position is offered. The empiricists point to the numerous cases of error in judgment, and the cases in which appreciation of space may be shown to depend upon definite sensations and particular associations. The

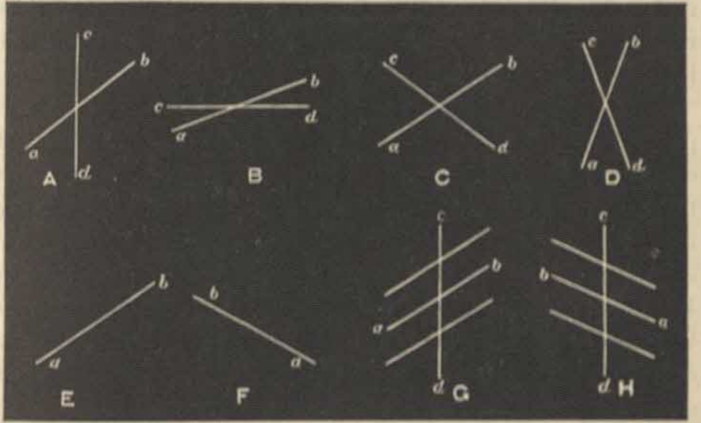


FIG. 109. — Hering's angle illusions. Careful observation shows that any of the oblique lines may be interpreted as crossing in some other than the plane of the page. (From Titchener, *op. cit.*)

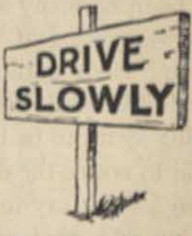


FIG. 110. — The transformation of right angles in natural objects seen in perspective.

nativist contents himself with the statement that the factors which, according to the empiricist, constitute space are altogether different from space as we know it, and also that it is inconceivable that space can be derived from anything not itself spatial.

The Space Discrimination of Those Born Blind. — The problem cannot ordinarily be approached directly, since the child has already developed his notion of space before he is able to tell us about it, and adults when questioned will have long forgotten what their first experiences were like and how they developed spatial ideas. As early as the seventeenth century, Locke suggested that if one could find a man who had been born blind and recovered his sight after he became able to describe his experiences, it would be possible to say how much of space perception was innate and, if it proved not to be innate, how it was acquired. Since then a fair number of cases of congenital cataract who were given sight have been observed. The lens of the eye is occasionally opaque from birth (cataract) and may be removed by an operation, and the patient be made to see. There is no great agreement as to what the patient can see, but the following statements seem to be in harmony with most results. The shape of objects is not recognized at all. One patient could not tell a square from a circle until he had had a chance to touch each. The field of vision is described as a confused mass in which everything seems to be in irregular movement. Some patients are said to notice the difference between geometrical figures when they cannot say in what that difference consists. One, after being told what an angle was, could count the angles on a figure and thus distinguish a triangle from a square, but for some time afterwards was not able to distinguish without this counting. The perception of distance was defective in each instance. Objects seemed in most cases to touch the eye, and in no case were they projected beyond the reach of the patient. There is practically no appreciation of depth. When all the evidence has been assembled, neither school is altogether convinced of the falsity of its own position. The nativist argues that the patient sees so little, because he transfers the associations developed by touch to sight. The patient thinks objects must touch his eyes because they touch his skin. The empiricist, on the contrary, argues that the patient would see nothing were it not for this same earlier experience, that interpretation from tactual experiences and from the light that comes through the lenses before the operation makes possible even such imperfect spatial judgments as are made.

Space as Concept or as Gestalt. — All the results we have brought together show that space is not a simple process. It cannot be dismissed by saying it is seen immediately. Rather the problem of space takes us back to the questions developed in the preceding chapter. Space is either a general notion or a series of general types developed through use or it is an immediate object of awareness as the Gestalt school claims. If it is a concept in its most general form, it involves the separate development of a number of subordinate types. These have been discussed as the perception of position on skin and eye, length and size, depth or distance from the eye, and distance and direction in auditory perception. Each of these types, which has resulted from a long process of trial and error in the life of the individual based on experience of a life time, is evoked by the suitable stimulation in a given mental and physical setting. The other alternative is that each of these units is an innate form which is applied at the suitable occasion. The Gestalt notion most resembles this last in that each unit comes as a whole, cannot be analyzed into parts and is not the result of experience. Probably more can be said for the influence of experience and the development of types. It is certainly more of an explanation if true. For to assert that space is a unit structure that just appears recognizes the facts of space, but can hardly be said to explain it. It may not be within the province of a science to make a decision on what is possibly a metaphysical question. At least we can express a preference for the theory that gives a hope of tracing the origin of space.

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CHAPTER XV

PERCEPTION (*Continued*)

PERCEPTION OF MOVEMENT

Visual Perception of Movement. — Movement is appreciated by three senses, the eye, the skin, and in much lesser degree by hearing. The appreciation by the eye has been most fully studied and is most adequate. Two methods of studying visual movements are used, the investigation of real movement and the study of apparent movements such as those of the moving pictures. Recently most studies have been devoted to the apparent movements since it is easier to reproduce them under experimental conditions. If we consider actual movement first, two forms of movement must be distinguished: one in which the movement can be actually seen; and a second in which movements are so slow that one infers that the object has moved from the fact that its position changes between two observations. The movement of a meteor belongs in the first class; that of the sun in the second. The slowest rate that can be really seen is one angular minute per second. Movements may also be too fast to be seen directly. An electric spark moving more than 15″ in a thousandth of a second cannot be seen to move. Movements may be appreciated when the distance covered is only 20″, a distance that is less than the limen of twoness determined by the two-point method. It approximates that found by Stratton by measuring the deviations from continuity of two lines brought together at their ends.

Simulated Movements. — The apparent movement of the moving pictures arises from showing different positions of the object taken at intervals of sixteen or so to the second and thus inducing the impression of movement. Studies beginning with Schumann and with Wertheimer have developed the laws that govern the movement. In the first place Wertheimer and Dimmick have demonstrated that the actual movement of a line can with difficulty if at all be distinguished from the apparent movement due to successive presentations of a line in slightly different positions. When shown first a line that actually moves and again two stationary lines that succeed each other at short intervals, the observer is only a little more than 50 per cent correct in deciding between them.

With these pseudo-movements as with the actual movements, three different stages and conditions can be detected. If a line is shown at one place and a second is shown less than some 0.030 seconds later at a point not more than 5° away from it, the two lines will be regarded as exposed simultaneously. If the second follow the other after some 0.150 seconds, one will be seen clearly to move to the other. If the interval between exposures be increased to half a second or so, the second will be seen to succeed the first, each in its own place. The most favorable periods between exposures vary with the length of time each line is shown, with the distance that separates them and the other features in the environment. For any given series of conditions it is possible to determine intervals between exposures that will either make the two lines appear to be simultaneous, have one move to the other, or have one succeed the other. The relation between length of exposures and the interval between exposures is mutual. If the first exposure is made relatively long, the second short, movement will be apparent even if the second is exposed before the exposure of the first is ended.

After-Images of Movement. — A fact that seems to indicate that movement induces physiological changes on the retina is the presence of after-images of movement. If one look for a time at a waterfall or a rapidly running stream and then look at a stationary plain surface for a time, the surface will seem to be moving in a direction opposite to that of the original. An endless belt of paper cross-barred with black and white stripes made to run on rollers will induce the same after-image of movement. The after-image shows the motion after a couple of seconds.

Eye-Movement Theories. — A theory based on eye-movement must take into consideration the fact that the perception is the same with actual movement and with the series of successive presentations of an object in different position. It must also consider the presence of after-images of movement. These two facts indicate that some change is induced in the optical mechanism or the cortex by the passage from one spot to another on the retina, and something identical or similar by the successive stimulation of different points on the retina. The after-image indicates that this effect remains for a time and then changes its character to produce the apparent reversal.

One of the first suggestions made was that movement was due to the eye-movements that were excited by the stimulation. This assumes that the eyes follow the movement and that we know the eyes move by the kinæsthetic sensations. It would also assume that the successive stimulation of different points would stimulate eye-movements which would give the same sensation. Three very definite factual objections may be made to the theory. First, experiments show that the movements seem to have a greater extent when the eyes are stationary than when they move. Second, photographs of the eyes while an illusion of motion is being observed indicate definitely that the eyes do not move as the theory requires that they should. Thirdly, two objects can be seen to move in different directions at the same time. Both could not be followed by the eyes, so that one at least must be appreciated in some other way than by direct eye-movement. We also have evidence that eye-movements are not readily appreciated.

The After-Image Theory. — A second theory suggested by Stern was that the movement of the object across the retina would leave a trail of after-images on the retina and that this trail would give a continuous picture of the track of the moving object. On this view the reversal of the motion in the after-image would be due to the familiar change from positive to negative after-image as discussed in Chapter IV. Real motion would leave an after-image which increased in brightness from the beginning to the end of the course. In the negative after-image the bright part nearest the bright object that made the image would become darkest. Those nearest the beginning of the path which had faded in the original would be less dark, and so the direction of movement would be reversed in the after-image. A film like an after-image has been reported by Dimmick, Mibai, and others in the pseudo-movements from successive stimulation of different parts of the retina. Here there can be no real after-image as there is no stimulation of the parts of the retina between the lines stimulated. If the after-image has become the symbol of movements, where objects really move, it is possible that this symbol is recalled by the successive presentation of lines near each other and constitutes the film which seems to fill the space over which the line is supposed to move.

The Gestalt or Immediate Awareness Theory. — Wertheimer came to the conclusion from the observations he made on apparent movement that movement was an immediate awareness, what he called the Phi phenomenon, that was added to the two lines when the circumstances were suitable. This was the first formulation of the modern form of the Gestalt theory.

Movement is not built up from experience and has no single component or several components into which it can be analyzed. It comes immediately because of the mental and neurological organization of the individual. The Phi phenomenon is not the gray film which connects the lines, nor is it muscle strain; it is just movement as we know it, and nothing more can be said about it. That we do have this notion of movement which is evoked when visual conditions are suitable is assured. Whether it is innate and needs no farther analysis or is built up from experiences of previous movements, with accompanying after-images and eye-movements, is more of a question.

Assuming that we can perceive movement, many interesting facts remain to be discussed of the way in which movements are interpreted under varying circumstances. Many of the phenomena may be the result of several different conditions in the outer world. Either the eyes or the field of vision may be in motion when many objects are leaving after-images. We may distinguish three conditions of motion, if we consider only the movements of objects and of the eyes. The eyes may be stationary and one object in motion; the eyes may be in motion, following one object, while the rest of the field is stationary; or, finally, the eyes may be following one object while other objects are moving in different directions or at different rates.

The first case has been discussed above. In the second case, one would have a clear image of the object that was pursued by the eye, while all other objects would be seen in blurred images or would be leaving after-images. Here we must explain how we know that the eye is moving. This might be, either through the sensations from the eye muscles, or by the after-images, or other signs of movement developed on the retina by stationary objects. The clear image of the object in flight would show that it was being properly followed.

while the after-images of all other objects serve as an indication of the movement of the eye.

Still more complicated, but nevertheless capable of explanation along the same lines, is the problem offered when the object and eye are in motion in different directions or at different rates. Here the total estimate is based on a comparison of the movement of the eye with the displacement of the image. In each of these cases much depends upon the estimate of the probability of movement. Even when it is a question whether the motion is of the external object or of the observer, interpretation is important. If one stands on a bridge over a rapidly running stream, it is quite easy to ascribe the motion to the bridge. The probabilities in the light of frequency of occurrence are that a small object like a bridge will be in motion rather than the larger river. Similarly, when you are on one of two trains standing in a station, and one starts, motion is ascribed to one or the other in accordance with your expectations. Not merely the sensory elements that give the perception of motion must be taken into account, but also the estimation through early experience of the probability that the object will or will not move.

RHYTHM

Most excitations which repeat themselves at short intervals tend to fall into rhythms. The tendency is most pronounced when there are regularly recurring differences in intensity, in duration or in intervals between stimuli, but rhythm is noted even when the stimuli that repeat themselves are identical in each of these respects. Rhythm is marked by two characteristics. The excitations tend to be grouped into units. Within the groups certain regularly placed stimuli are increased in effectiveness. We call this increased prominence the accent. Auditory and kinæsthetic impressions show rhythm most easily; tactual and visual, not so markedly. The accentuation in rhythm may be produced in a number of different ways all of which give the same effect. It can be given subjectively as well as objectively. If one listen to the ticking of a clock or the beats of a metronome, it will be noticed that they tend to form units, and that the character of the unit, the sound that is accented, will vary from time to time, and within limits, can be changed at will. Objectively, it is possible to emphasize one unit in the measure, either by increasing the intensity of the note to be accented, or by increasing the length of the note. This is evidenced by a comparison of ancient with modern verse. While the former produced its rhythmic effect by lengthening the syllable, English poetry obtains the same effect by increasing the intensity of the syllable. A similar difference in the way of producing effects can be seen in music of the organ and of the piano. On the organ where the intensity is constant, rhythm is obtained by increasing the duration of a tone, while on the piano, accent is given by increasing the intensity of the note. The rhythm is the same in both cases. In fact, men who have played the organ for years often do not notice either the difference in the effect or between the way in which it is produced on the organ and on the piano. Not only may accent be given by changing the character of the note, but also by changing the intervals between the notes. In a measure of three notes of the same intensity and duration, if the first interval be increased, the first note will be accented; if the second interval be increased, the last note will be accented.

Conditions of Rhythm. — Rhythm is appreciated most readily in series of movements or sounds, but is also readily induced in series of visual or tactual impressions. The intervals that may separate stimuli and still permit rhythm vary for the different senses. Visual impressions must not be separated by less than 0.3 of a second nor by more than 2.4 seconds. If the sensations are closer together, the after-images are disturbing. Auditory impressions need be separated by little more than a tenth of a second. The most satisfactory rhythm is produced when the stimuli are separated by about 0.6 of a second. The more rapid the rate of succession, the greater the number that may be brought into a single unit. In very rapid beats of the metronome, two hundred per minute or so, it is possible to combine as many as eight beats in a single unit. The size of the unit may within limits be varied at will. When they are sixty or less per minute, it is with difficulty that two may be grouped. In general, Woodrow found that in a series of tones separated by equal intervals in which every other note or every third was more intense, the group would begin with the more intense tone. When intensities were equal but alternate notes were longer, the longer note would start the measure. The grouping and the accent depend upon both objective and subjective factors.

The Theories of Rhythm. — Two theories to explain these various facts of rhythm are at present current. One is that rhythm has a motor origin, that the impulse to beat time is universal, and that any external series that will call out this tendency produces the rhythm. Genetically, it is argued that rhythmic movements are inseparable from bodily activity. The movements in physical labor naturally take on a rhythmic form, and this may have been transformed into the dance, which in primitive races frequently develops from the daily work. From the dance, rhythm was introduced into music and reached its present degree of complexity. Whenever new impressions from any of the senses are given in succession, these old movements of the dance or of work are evoked spontaneously.

Attention Theory of Rhythm. — A second theory emphasizes the similarity of the conditions of accent to the conditions of attention. Intensity and duration were found to be objective conditions of attending. From the other side attending to a stimulus tends to increase its efficiency and to give approximately the same effect as increasing the intensity of the stimulus. This explains the effect of the preceding and succeeding intervals. A period of expectation is an important factor in arousing attention. Where a note in the rhythmic group has been preceded by an interval, expectation increases regularly during the preliminary wait; and when the stimulus finally makes its appearance, it is more fully attended to and seems more intense than impressions that have been preceded by the shorter interval. Less obvious is the explanation of the accent when a longer interval succeeds the stimulus. This seems to offer opportunity for full attention to the stimulus after it has stopped, and increased attention increases the apparent intensity. It seems probable, from observation and particularly from the fact that an interval affects the accent of the note that preceded, that the appreciation of the rhythmic unit takes place at the end of the measure. The unit is heard as a whole at the moment it is completed rather than bit by bit as each impression comes to consciousness. The attention theory, then, would hold that rhythm is induced by any circumstance that makes some one or more elements in the series of tones occupy a more important place in consciousness than the others, and that the whole group becomes a unit for attention.

While the attention theory has some advantages in explaining why the emphasis is placed as it is, it seems probable that a considerable portion of the sensory content of the rhythm is supplied by the motor contractions which may come as a result of the subjective accentuation. A good case can be made for either theory, and they are not at all contradictory or out of harmony one with the other.

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PERCEPTION OF TIME

Problems Concerning Time. — Time offers many of the same problems as space. It, too, is a universal characteristic of all our experience, and has received the same discussion as to whether it has real existence or is merely subjective. As with space, we may ask how short a time can be noticed, and how we appreciate longer intervals. The traditional question, how short a time may be experienced, receives a different answer for each of the senses and combinations of senses. It is much shorter for hearing (.002) than for sight (.044) and may rise to 0.16 second when one stimulus is given by sight, the other by the ear. When one turns to a study of the longer times, it is found that the estimation of time and even our awareness of the passage of time varies greatly with the duration of the intervals involved. If one is asked to listen to times of different length, certain times are at once pronounced very short, too short to be perceived with comfort, others as too long to be easily appreciated. Times under 550 σ (σ means thousandths of a second) seem too short, are hurried, and not adequately comprehended. This is also just a little shorter than the most favorable interval for the appreciation of rhythm. On the other hand, times of more than 1800 σ seem very long, and it is with difficulty that they can be brought within the span of comprehension. At about four seconds, it is no longer possible to bring the events within a single compass; one reaches the limit of a single span of time so far as it can be experienced immediately. It should be noted that this is also approximately the length of the primary memory. Within this period events may be held in a single span of memory, and the memory image can be used with the same care and certainty as a sensation. By virtue of this fact four seconds are said to constitute the immediately experienced present.

The Different Factors in the Perception of Time. — These two lengths of time which may be looked upon as critical are of theoretical interest. Earlier workers who measured the errors in comparing one time with another reported that there was a tendency to overestimate times shorter than about three fourths of a second and to underestimate times longer than that. Woodrow repeated these experiments to find that his subjects showed no constant tendency to overestimate short and underestimate long times. He used many more observers and quite as careful methods as the older men. He did find that times between 0.66 and 0.80 seconds were more accurately tapped in synchrony with clicks set for that distance and that they were also the times most accurately reproduced. This three-quarter second interval also approximately coincides with the point of division between the times felt as very short and those which seem of moderate duration, and furnishes additional evidence that there is a real difference in the means of estimating longer and shorter times. Some light may be thrown upon the conditions of the perception of time by a study of the factors that influence the comparison of intervals. First, anything that influences expectation is important. Thus, if sounds are separated by equal intervals and every alternate note is more intense, the interval that precedes the more intense sound will seem to be lengthened. This has been explained as due to the surprise induced by the strong tone, which increases the strain ascribed to the preceding interval.

Illusions in the Perception of Time. — Just as in space, the filling of an interval also influences its appreciation. With short times it is found that filled time seems longer than empty. If the time be longer, and one be permitted to read during one period and to do nothing during the other, the time spent reading seems shorter. The probable explanation of the latter difference is to be found in the fact that the empty time is really filled by noticing strains and other internal sensations, while, during the time occupied in reading, these strains are not present. One forgets one's self and the passage of time in the interesting event. For longer times the filling seems to have a markedly different effect according as the time is regarded as it is being lived through, or as it is viewed in retrospect. While passing, time in which one is occupied fully and during which much of importance is happening seems short, but when viewed in retrospect it seems long. Empty time, on the other hand, seems long in the passing but short in retrospect. During convalescence from a long illness the days drag interminably, but later the period seems inappreciable. Periods filled with very loud tones seem longer than periods of the same absolute length filled with fainter tones.

Woodrow discovered a time illusion very similar to the Müller-Lyer illusion in visual space. If a period is preceded by a long tone to mark its boundary and is ended by a short one, it seems about 30 per cent longer than when a short tone initiates the period and a long one ends it. The bounding tones were 0.46 and 0.06 and the interval 0.50 sec. If the beginning and end tones are both long, the period is lengthened but only in proportion to the length of the first tone. The explanation offered is that the first tone is unintentionally added to the period, while the observer accepts the beginning of the terminal tone as the end of the interval and gives his judgment at once.

Theories of Time Perception. — Attempts at a theory must take all of these facts into consideration. We must distinguish three ways of appreciating time. The first applies to the very short intervals, those under 600–700 σ, below the indifference period. These, it has been suggested, are appreciated in terms of rhythm, since under that limit stimuli may be easily grouped into rhythmic wholes. The intervals are too short to be appreciated for themselves, they cannot be attended to, and so do not reach their full development. The second is effective for times between 600 or 700 σ and two to four seconds; this is real time. This period of most adequately appreciated time is sometimes referred to as the immediate present. It is apparently appreciated in terms of internal experiences, expectation processes, and other more definitely kinæsthetic sensations. The length of the time is estimated by means of the intensity of the strains. Short times give strains no chance to become strong, but their strength grows with the longer times. Strains of the muscles that accompany attention, strains of expectation, even strains that come with respiration or with holding the breath, have been asserted to form the basis of the appreciation of the passage of time. The influence of the strength of the limiting stimuli would suggest the importance of the strains of attention in the estimation of time, as would the effect of the content of time. When the interval is empty, attention is more fully attracted to the passage of time, the strains are more pronounced, and the time seems longer. In the same way with longer intervals when there is nothing to do, the strains of expectation occupy consciousness and time seems long. When one is busy, attention is occupied, strain and relaxation alternate rapidly, the strains never rise to great intensities, and in consequence one is not impressed with the fact that time is passing.

Times longer than from two to four seconds are apparently not directly experienced in the passing, but are only experienced as past. They fall outside of the present, are constituted for the most part by memories of past events revived in the present. They are estimated in terms of events that have happened in them, in terms of the occurrences which fill them. In this they differ altogether from the shorter intervals that may be directly appreciated, and in consequence show the reverse illusions. Thus, times that are filled with interesting events seem long when they are looked back upon, although they seem short in passing; while times in which nothing happens seem short in retrospect, although extremely long in their passage. It is this that explains the seeming decrease in the length of the days and weeks with advancing years. When one is young, all is interesting from its newness, and is always attended to; as time goes on, nearly everything becomes familiar, and receives less and less attention, and so less and less is remembered in retrospect. In general, times depend upon an appreciation of that which fills them. Very short times are apparently known from rhythm, longer times from the physiological processes, contractions and what not, that give the feeling of expectation and strain; while intervals longer than from two to four seconds are appreciated from the events.

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Reading as Perception

One of the best means of studying the laws common to all perception is furnished by reading. Here the material is relatively simple and we have fairly full experimental evidence concerning the different phases of the process. First it may be asserted that the word, not the letter, is the unit for reading. This is demonstrated by the experiment on the distribution of attention. As was said in connection with attention, five or six letters are the maximum that can be distinguished on short exposure, but, when combined into words, twenty-five to thirty letters may be read at a single exposure of $\frac{1}{10}$ second. Evidently something must be added to what is seen, or the word must be read as a whole rather than by single letters. There is evidence that both processes go on in some degree. Zeitler and the writer found that the reader was influenced by the general form of the word as determined by the relative positions of high and low letters, the length of the letters, etc. This is indicated again in print by the fact that one is much more likely to make mistakes and to have greater difficulty in making out the words if the upper parts of the words are cut off than if the lower be covered.

On the other hand, the proofreader's illusion indicates that there is a constant tendency to supply letters or parts of letters from memory, to add centrally to peripherally aroused sensations. The writer found that if words were printed with letters omitted, with blurred letters, or with substitutions, and shown for a fifth of a second or less, they were read in a large proportion of the cases as if perfect. The readers would occasionally give reports of the character of the letters, supplied or transformed, which indicated that they belonged in the class of the centrally aroused sensations. The letters that were supplied or replaced were faint, had a peculiar color, or seemed to be less permanent than the others. The likelihood of reading the misprinted word as if it were correctly printed was much increased, if a word associated with the word to be shown was called before the exposure. This gave the right attitude or setting for seeing the word intended. That supplementing is a factor even in the simplest reading is shown by the large number of misprints that are overlooked, some even by the most accurate proofreaders. The supplements in this case are not so permanent as are those in optical illusions. The latter persist for a considerable time in spite of all that one can do, and can be destroyed only by a long period of practice, but the proofreader's illusion vanishes when first one looks to make sure that a mistake has not been made.

Reading Pauses. — One might deny that the conditions of ordinary reading, in which all the time that may be desired is given for looking, are similar to those in which the exposure is limited to a period too short to permit eye-movements or wandering of attention. Recent studies of the mechanism of reading show, however, that the conditions are not markedly different. In the first place it has been found that, while reading, the eyes do not move steadily along the line with full time for the observation of all details, but make a few brief pauses. Photographs of the eyes as they move along the line show that they stop only three or more times in a line of ordinary length, and then for but a very short time, approximately a fifth of a second. The number of stops varies greatly with the character of the material to be read and with the experience of the reader. In reading a novel or similar light literature, the number is a minimum, and rises to a maximum with difficult material, in proofreading, and for children who are learning to read. One really takes a series of snapshots of a line and pieces them together, rather than reading continuously. There can be apparently no reading while the eyes are in motion; they move so rapidly that nothing but a blur of after-images is left on the retina, and as this gives no knowledge, we have learned to pay no attention while the eyes move.

Reading a Process of Supplementation. — These facts prove that ordinary reading consists in building up, from the vague outline of the word and the few letters clearly seen, the word that we seem to see. The construction of the word is made possible in small part by connecting with the few letters seen other letters that have frequently been found with them before. More frequent are the cases in which the form of the word and the few letters seen recall the image of a word as a whole. Like all associations, these are under the control of the mental attitude, largely determined by the context and the knowledge that the reader can bring to the reading. The influence of the context can be seen in the different pronunciation and interpretation of a word composed of the same letters in different contexts. 'Lead' has one pronunciation when the subject of the sentence, another when it is the predicate, and we do not think of the one when the other is meant. The meaning is determined by the context, and what has gone before. Still more striking is the difference in pronunciation and interpretation that attaches to the same group of letters in different languages. *On* has an entirely different sound and meaning in English and in French, and many other illustrations could be found. Suffice it to say that the sounds or ideas that are aroused depend very definitely upon the context.

In reading it is evident, too, that the process of perceiving or of interpreting is not complete when the word as such has been seen. The process of translation into ideas follows. Sometimes one sees the words and follows them along with the sound or the spoken word, and thus has the ideas produced indirectly. Experiments show that to depend upon translation through internal speech is of no advantage and makes reading unnecessarily slow. More frequent in the adult is the immediate translation of the words as seen into images or ideas of some sort. As one reads in the most complete way, pictures or more abstract ideas accompany the reading. The clearer the style, the more immediately do the ideas follow upon the perception of the words and the less prominent are the words, until with a maximum of clearness the words are largely neglected and the meaning alone comes to consciousness. This meaning may take the form of picturing the scenes described, of merely appreciating the abstract meaning, or of something intermediate. In any case, the outlines of black and white that constitute the words start the association processes that lead to the ideas, and these associates are controlled by the larger setting and wider knowledge of the individual at the moment

The process is much like that in ordinary recall except that the stimuli are constantly received from the words. The revival of the earlier experiences is controlled by the laws of association and by the context in a degree that amounts in many cases to new construction.

Understanding Spoken Language. — A similar process occurs in listening to another's speech. One does not appreciate how small is the proportion of a conversation that is heard distinctly until one attempts to follow a foreign language. Then it is seen that what must be perfectly clear to a native as a vehicle for ideas is really only a series of grunts and hisses with an occasional word clearly enunciated. Suggested by these, the words or the ideas are supplied through association. Bagley has shown that there is a process of filling out the imperfections of sounds, similar to the interpretation of letters in reading. The laws of supplementing are practically the same in the two cases. Something is given by the ear; this suggests words as one would speak them one's self or as they would look on the printed page. This is all that is really appreciated, and even when one listens for the words, the imperfections are not noticed. When one hears a strange accent, the different deviations from the sounds one is accustomed to are overlooked, the man is assigned to his region of the country, and then no more attention is paid to the speech characteristics, unless one be interested in phonetics or have some other purpose in hearing the sounds, and in such cases the sense of what is being said is very likely to be lost. Artificial languages gradually take on the same character. The separate elements become united into word units, and then acquire meaning, as do words themselves. This comes out particularly clearly in learning the telegraphic language. There at first the sounds are heard as small groups and put together painstakingly and slowly into letters, but gradually words are heard as wholes and the meaning is suggested by a few words and omissions are filled in as in ordinary speech. Supplementing follows the same laws as in reading or listening.

The General Laws of Perception. — We may extend the laws that have been stated for reading and listening to include perception in general. Just as in reading, a few cues are given by the form of the word and a few letters and we build on them whole words and ideas, so in all perception some slight sensory stimulation serves as the basis for the elaborate constructions that constitute objects. Different schools have different ways of stating the process of construction. One is content to say that all is explained by the evocation of old habits, which supplement the stimulation with slight vocal responses. Both of the theories developed to explain the unit of experience have been applied to the perception process. Both agree that perception gives us the original concrete unit of experience. What that is on the two different theories was discussed in Chapter XIII. Both agree that it is what the observer regards as the true and real. It is for practical purposes the real object.

Memory Additions. — The more empirical of the two theories believes that the object is the product of present and past experience. In some measure it is the product of the arousal of a part of the total by stimuli that have been frequently connected with it in the past. Frequency of connection and the general setting, mental and physical, determine what the supplementation shall be. Filling the blind spot is the best illustration of this form of completion, although supplementation of missing letters in words, and filling in of lacking arcs in a circle are other instances. Illusions are due to the wrong connection being brought in through dominance of the wrong association or of the wrong context. These supplementations are restricted to developing parts of the object or view. They are, however, highly important.

Perception as Evocation of Types. — More important and more common is the instance in which what we call seeing a thing consists in calling up a form that has resulted from frequent corrections in the past of what we take to be the same object. We recall not a single element on the basis of its connection with other elements, but we evoke a whole that is the result of all our experiences with that object. As soon as an outline shows its likeness to a man, the full human figure is given it. If it is recognized as a particular man, his features take form, no matter how little we actually see of them. The changes are both positive and negative. All elements that are not consistent with the type object are eliminated and all that are needed to complete it are added. Shadows are overlooked. If a piece of white paper is torn in two and one part put in full sun and the other in shadow, the two seem of the same degree of whiteness although one may be many times as bright as the other. You see the sun and you may be aware of the shade but, unless you look with the purpose of comparing brightnesses, the color or whiteness is still the same. You have a standard white and see it, making allowances for the different brightnesses. Each object is similarly standardized, and that standard object comes at once as the perception occurs.

The Gestalt Theory of Perception. — For the representative of the Gestalt theory the process of perception is described in almost the same terms except that the Gestalt is assumed to be independent of experience. Then, too, he would not admit the presence of elementary sensations as conscious at the time, any more than would the 'type' theorist, even if he does not make clear exactly what the relation is between the sensory stimulation and the arousal of the final Gestalt. He does not deny that there must be some stimulation of the sense organ, but he is so intent on the assertion that the percept comes as a whole that he gives very little consideration to the way it may be aroused. At least no distinction should be made between the immediate results of the stimulus and the process of completion. There is but one process and that is the whole. The representative of the Gestalt view also specifically denies that the Gestalt is the product of experience. It is something given immediately to the individual. Its development cannot be and should not be traced. For this theory perception is a simple process which may be described, not explained. Perception is merely the appearance of a Gestalt. We cannot say why it appears at a given moment or how it is related to the earlier experiences of the individual.

Summary. — However different in details these three theories may be, they are alike in asserting that perception is the process by which we know things, that knowing involves the addition of old habits of response, or of old and corrected experiences, or of a Gestalt to the occasion for perceiving. Theories may differ as to what is added, and as to how what is added developed, but they are alike in believing that perception involves more than the stimulus. The latter two theories are also alike in believing that the product of perception is the accepted reality, that it is an organized whole, although they differ as to whether the reality developed through experience and has been organized as the result of experience or whether it is immediate and needs no further explanation or justification. If we accept what is agreed upon, the settlement of the differences may be regarded as unessential for the moment and can be left to the progress of time for their settlement.

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CHAPTER XVI

MEMORY

MEMORY follows close upon perception in the place it fills in daily life. That we can refer accurately to experiences of the past is one of the phenomena we call mental that is most frequently commented upon. Both failures and successes in remembering are matters of popular discussion. We are interested in how we remember and in the laws which determine how to learn most readily and to recall most completely rather than in any abstract capacity of memory. We mean by memory the capacity for making accurate references to events of the past and using them in many ways as if they were actually present. Memory in effect is making use now of perceptions that may have been real at different intervals in the past.

We have already considered the fundamental processes involved in memory: the facts of retention; the formation of connections in what are called associating or conditioning, and the characteristics of the reinstated experiences. In this chapter we are interested in bringing together the results of experiments and observations as to how the various part operations of memory may be carried on to the best advantage and of the general laws that determine the various phases of the process. It is convenient to divide the stages of memory into four: learning, retention, recall, and recognition. The division is arbitrary in places, since there is a considerable amount of overlapping, but the distinction makes possible a convenient division of the discussion. Learning is the formation of connections which make possible recall; retention is the mere persistence of these connections as changes in the nervous system; recall is the revival of the experience through these connections, and recognition is the reference of the revived experience or its representative to the time of the original occurrence. Although the general principles of remembering are processes involved in associating and conditioning, a large number of facts in connection with their applications in learning and recall have been developed which are of great practical and theoretical importance.

Two forms of memory may be distinguished. One is the revival of the concrete experience in its original form. The other is the recall of words or symbols which represent events, or of the symbols or words for themselves. The two differ in the laws that control the recall. Memory of concrete objects may be by means of a reinstatement of the images of the earlier objects, or it may be a recall of the words that represent them. If words are used, some problems arise from translating the images into words and the words back again into images. When images are retained for themselves or events are referred to as events alone, there are also errors in revival that are characteristic. We ordinarily call the memory for concrete objects, observational memory and memory for words or symbols, rote memory.

MEMORY OF OBJECTS AND EVENTS

Observational Memory. — Observational memory has great practical importance because the memory of concrete events and objects is the main source of evidence in courts of law. A witness must report on what he sees and hears. Much study has been given to it in that connection. It is also the method that is used in reporting the events of the day in conversation. The popular reports that find their way into scientific discussions depend upon this sort of memory. That explains why so little reliance can be put upon chance observations and upon any science built upon them. All accurate scientific results must rest upon records carefully made at the time of the experiment. Many experiments have been made to test the accuracy of observational memory. A picture or a number of objects are shown to a group, or a carefully acted scene is presented before them. They are asked after the lapse of an interval to give a complete description.

Rules for Observational Memory. — The results of the experiments prove that the accuracy of recall is influenced by the attitude of the observer at the time of observation and by the character of the material that he observes. Secondly, it is dependent upon the time that elapses between the observation and the report. Thirdly, fidelity of report is affected by the attitude of the witness or observer at the time he described what he has seen, by whether he reports spontaneously or is questioned, and by the character of the questioning. If at the time of observation one is expecting the stimulus, one sees more than if one is surprised. A man will see more of what he attends to than he will of what is not in harmony with his purpose and so is not noticed especially. People in general are more likely to notice and so be accurate about persons and things than they are concerning abstract qualities. After things and people, the adult reports with greatest definiteness on form and then in order of certainty on position, number, and lastly color. Children are much more inaccurate than adults in all except possibly the observation of colors. Special practice in observation of any kind will greatly increase the accuracy of observation. Practice is of some general value in calling attention to what is likely to be overlooked, and in enabling the observer to attend especially to that. Accuracy is increased, too, by describing in words what is seen, and remembering the words rather than trusting to the images alone. Thus, if one will count the windows in a building as one looks, one will remember the number, but if one attempts to count them in the memory picture, the result is very likely to be wrong.

Effect of Lapse of Time on Accuracy. — The effect of time is always in evidence. Dallenbach found that forgetting took place rapidly at first and then more slowly, a law that holds for forgetting all types of material. Thus immediately after exposure, 10 per cent errors were made; after five days this had increased to 14 per cent; after fifteen days, to 18; and after forty-five days, to 22. The material used consisted of pictures, and the percentages were obtained by counting the number of objects in the picture and determining what per cent of them was recalled. It will be noticed that there was the same increase in the number of errors between one day and five as between five and fifteen, and fifteen and forty-five.

Most errors of report that develop at the moment of recall are due to the suggestion of objects that were not actually seen. Any idea that presents itself is certain to suggest others, and this suggestion may lead the observer to think that the corresponding object was actually present. This is an extension of the tendency for what is present to suggest at the moment of observation other things that are not really seen. Something is definitely recalled, and this suggests something else that usually goes with it. The arousal of the idea may be accepted as constituting evidence that the object was really seen. Very striking is the influence of questions in increasing the number of errors. If the individual is told to tell all that he saw, he will make a report that is approximately 90 per cent correct. If he is questioned as straightforwardly as possible about the objects in the picture, the errors will increase so that he may have only 70 per cent correct. The advantage of questioning, which makes it essential that a witness be questioned in court, is that many things he might report on will not suggest themselves spontaneously. Experiments show that the spontaneous report covers only 25 to 40 per cent of the total number of objects present, while questions will increase this range to 50 or 65 per cent. What is lost in accuracy is gained in range. If leading questions are asked, particularly if they assume a wrong answer, the percentage of errors is increased much more. If one asks the color of the dog in the background, when no dog was present, about half of the individuals, even of superior intelligence, will give some color.

ROTE MEMORY

Experimental Methods. — Most work has been done on the laws of rote memory. Careful experiments on memory were first made by Ebbinghaus in the eighties of the last century. To avoid the variation in degree of familiarity and interest that might attach to words or any other material that has meaning, nonsense syllables were selected as the material to be learned. These were built up of consonants and vowels, two consonants with a vowel between. All combinations were excluded that chanced to make sense. Series were selected by lot from the mass of syllables. Ebbinghaus wrote his series upon cards and then learned them by shuffling the cards. Most later workers have arranged the syllables upon some sort of revolving drum that exposes them at regular intervals and for definite times. Syllables are read aloud as they are exposed, and repetitions continue until the series can be said through without mistake either once or twice, according to the criterion chosen by the particular investigator. Ebbinghaus used the amount of time spent as his measure, but he shuffled his card regularly so that time and number of repetitions gave approximately the same result. Most later writers have used the number of repetitions as a measure.

The Measurement Scale for Memory. — Three measures of the degree of learning have been used. The first, known as the 'savings method,' was the one used by Ebbinghaus. It consisted in relearning the series after a definite interval, usually twenty-four hours, and assumed that the difference between the time required for learning and for relearning was a measure of the amount retained. This also measured the value of the method of learning used. In a second method, the method of paired associates developed by Müller and Schumann and extensively used since, the syllables are learned in pairs and the amount retained is measured by showing the first member of each pair and asking the observer to supply the second. The percentage of correct answers indicates the amount retained. In many experiments, the time required for speaking the second syllable is measured. This serves as an indication of the strength of the association for individual pairs. The shorter the interval required, the stronger is the association. A third method, less frequently used, is the method of promptings. In this the observer repeats the series of syllables as far as he can and is then prompted when he fails. The number of promptings is used as the measure of his retention.

Each of these methods has given valuable results. They frequently supplement each other. The first measures primarily the effective and latent memory of the whole; while the second and third permit a study of the effective connections between members of the pairs. One measures potential memory or liability to recall; the others, the actual recall.

THE LAWS OF LEARNING

Effects of Individual Repetitions. — Ebbinghaus began his investigations of memory by determining how the results of different repetitions compared. This was necessary since it was possible that a repetition at one stage in the learning might have greater or less effect than at another. Ebbinghaus tested this by repeating a series of syllables eight times and then finding the time required to learn to the point of one errorless repetition after twenty-four hours. He then repeated another series sixteen times and again learned after the same interval. These experiments were repeated up to sixty-four repetitions of a series. Within these limits the amount retained after twenty-four hours was directly proportional to the number of original repetitions. Miss Mibai extended the range to two single repetitions and found a regular increase from two to eight. The last repetitions were no less effective than the first as measured by the amount retained. The diagram shows that the results, when plotted, lie almost in a straight line. Each repetition resulted in a saving of about twelve seconds in the time required for relearning. This experiment also brings out the fact that learning is never absolutely complete or perfect. Perfect learning at the moment will show defects in a few hours or days. Krueger showed that the effect of each repetition was the same up to approximately 100 per cent over learning. From there on the

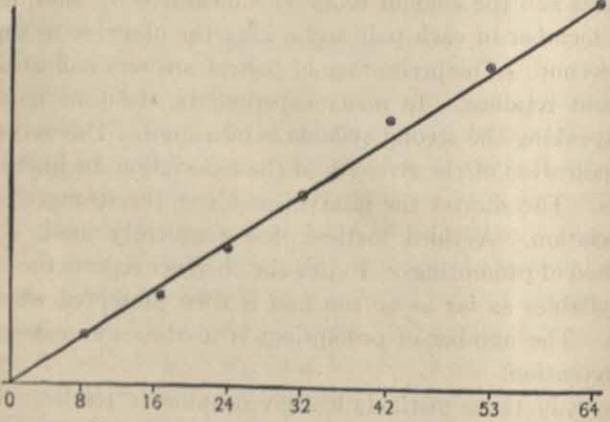

FIG. 111. — Shows the increase in amount retained after twenty-four hours with the number of repetitions. The number of repetitions is plotted on the horizontal, the saving in seconds on the vertical axis.

repetitions decreased in effect. So far no evidence of an experimental kind has indicated that one ever reaches a point in learning beyond which repetitions do not increase the likelihood of retention. It probably is reached in the 'two times two are four' experiences of everyday life, but the evidence is inconclusive.

Relation between Length of Series and Number of Repetitions. — One of the more striking facts in connection with learning is the great increase in the number of repetitions required for the longer series as compared with the shorter. It is found that an adult can remember from 6 to 8 syllables or 11 to 13 numbers with a single repetition, while Ebbinghaus found that it took 13 repetitions to learn a series of 10 syllables, 16.6 for 12, 30 for 16, 44 for 24, 55 for 36. Meumann has questioned Ebbinghaus' results, not on the factual basis, but for the interpretation. He argued that since the relative increase is much greater between twelve and sixteen syllables than between twenty-four and thirty-six, there is no increase at all with the longer series. It was evidently a temporary confusion of relative increase with absolute. Most later workers confirm Ebbinghaus' general results. It is assured that, as the number of syllables in a series increases, the number of repetitions required for learning increases much more rapidly than in proportion to the increase in the number of syllables. The most striking increase is seen when the series is just longer than can be learned with one repetition. The number of syllables that may be learned at a single reading to be repeated immediately has been called the memory span, or primary memory. This varies very markedly with age, with training, and with the individual. It may be much increased by training at any age. According to Meumann, children from seven to nine can usually retain no more than two or three nonsense syllables, while the practiced adult retains seven or eight. Whatever the age, as soon as the number of syllables in the series goes beyond the memory span, the number that can be learned with one repetition, the number of repetitions required to learn the series is not one but from four to ten repetitions or more.

Effects of Grouping. — Learning a series not only forms associations between the contiguous syllables of the series, but knits the whole group together by associations formed between all of the syllables, however widely they may be separated. Ebbinghaus demonstrated this by learning certain series and then making up new series that should consist in part of the syllables of the primary ones. Thus, he would select syllables that had been separated by one syllable; and he found that the new series could be learned more easily than new syllables. He repeated the experiment, using syllables that had been separated by two, three, etc., syllables, up to those that had been separated in the original learning by as many as eight. He found in each case that a saving could be shown as compared with entirely new series. The results prove that associations are formed between the remote as well as the contiguous elements in a series. He also showed that associations are formed in both directions, backward as well as forward. Relearning a series backward saves about one third of the time which is saved in relearning forward. It has also been shown that some connection is formed between the syllable and its position in the series. Syllables that are relearned in the same absolute position in a series are relearned more easily than when they take a new position. If the syllable is the third or the seventh in the series and is kept in third or seventh place, relearning is easier than if it is shifted to second or fifth place in the new series. All of these bonds of connection aid in making the series a unit.

Effects of Rhythm. — Anything that serves to unite the syllables into minor units is of advantage in aiding learning. One of the means employed most frequently is rhythm. In repeating a series, the syllables are practically always combined in rhythmic units and given an accent. Learning in the natural rhythm is much easier than in a forced rhythm or without rhythm. The natural rhythm varies with the individual and probably also with the race, but whatever the rhythm used, some benefit is derived from it. The rhythmic unit also serves as a subordinate group within which associations are much stronger than between contiguous syllables of different groups. Müller demonstrated this by first learning series in trochaic rhythm and then forming from the syllables two sets of new syllables. In one of these, the syllables were relearned in the same measures as in the original series; in the others, the syllables were contiguous but had belonged to different measures. The former showed a saving on relearning equivalent to five repetitions; the latter, no appreciable saving. This strong association within the group holds, not merely for the grouping in rhythmic units, but for any grouping. In learning nonsense syllables, practically no association is formed between the first syllable of one series and the last of the preceding. In common life little connection is established between conversations on different subjects with different persons, even if one immediately succeeds the other. On the other hand, where material to be remembered is broken up into smaller groups of a larger series, members of these groups are more closely associated for themselves, and learning the groups aids in learning the total series. This formation of subordinate groups is of great practical importance, and will be referred to in connection with the development of meaning.

Learning by Whole and by Part. — One of the interesting practical rules developed by the early experiments is that it is quicker and easier to learn a selection of poetry if it is read through from beginning to end until it can be repeated without mistake, than if it is learned in the method, usually employed by the uninitiated, of learning a line or two at a time and gradually building these up into the whole. The first investigation by Miss Steffens showed a saving of about one tenth of the number of repetitions for adults learning poetry. The evidence still seems to favor the whole method for bright adults learning sense material, although several investigators have found divergent results. Meumann found learning as a whole required fewer repetitions, but took longer time unless the learner were held to a fixed rate. This was because he lost interest when he could not see that he was making progress and so slowed up. Meumann suggested an alternative method in which the whole would be read until it was seen what parts were difficult, and then special repetitions be given to those portions.

Pechstein tried, for rats learning a maze, a modified part method. Instead of learning the parts successively, he would have the rats learn the first of four parts into which he divided a maze. When that was learned, the second part would be added to it, and these two learned as a whole, then the third and the fourth would be added in the same way. This he called the progressive part method. It was found easier than the whole method. Another modification learned the last part first, then added it to the next to the last, and so on. This also gave better results than either the whole or the pure part method. The strength of the argument from these results is weakened by the repetition of the experiment by Miss Hanawalt. Miss Hanawalt's procedure differed from Pechstein's only in that the maze was more complicated, the parts had no similarity to each other, and rats were used that had had preliminary experience in maze learning. Her results gave just the opposite results from Pechstein's. Learning as a whole gave better results in each case than any of the part methods.

Numerous other investigators have made experiments on the problem. While the methods are not always comparable it seems that the whole method gives better results, the more thoroughly trained the subjects are, and the more intelligent. Children are more likely to show better results with the part method than are adults. Longer selections are more distinctly better learned by the whole method than are shorter selections. Sense material shows the advantages of the whole method more than does nonsense material. While the problem cannot be regarded as completely solved, the evidence that the whole method is more satisfactory for intelligent trained adults learning relatively long selections of sense material is pretty strong.

Reasons for the Advantage of the Whole Method. — If we accept the whole method as having an advantage, three factors would serve as an explanation:

1. It saves much of the time ordinarily wasted in needless repetitions. In the part method, the first part of the selection is repeated more times than necessary through going back to connect the later learned lines with the earlier. There are several times as many repetitions of the first as of the later parts.

2. Needless associations are made each time the reader goes back from the end of a line to its beginning. These take time and also may interfere with the formation of the correct associates.

3. As was said above, the connection of a word with its position in the selection is of some advantage in learning, and the whole method always retains the absolute position of each word.

The part method has the advantage of letting the learner appreciate how much he has learned. This encourages him to go on to learn another part. In the whole method there is no definite indication that anything has been acquired until the whole is learned. The younger and less intelligent are more likely to be discouraged by this and to reduce effort and speed of reading. There also is less to hold the learner to his task in nonsense material than in sense material.

Meumann and his pupils have shown that certain intermediate methods may improve on the strict method. Thus, it is frequently an advantage, after a number of repetitions of the whole, to repeat several times the parts of the selection that offer special difficulties, and to learn them without making unnecessary repetitions of the easier portions. One can also obtain some of the advantages of the part method by making short pauses at certain places. These pauses seem to attract particular attention to the words preceding and succeeding them, without the disadvantage of forming useless connections. In general, it is recommended that one read through the selection to be learned a few times as a whole; then, as fatigue comes on, introduce the pauses. When it becomes evident that certain parts are offering special difficulties, an extra number of repetitions can be given those parts until they are learned. Finally a few repetitions of the whole can be made to weld all together.

Distributed Repetitions More Effective. — Another law that is equally well established, quite as important in practice and even more interesting, is the so-called law of divided repetitions. Briefly, this is that the more the repetitions are distributed over different days, the fewer the repetitions required and the more thoroughly the material is mastered. This problem was first carefully investigated by Jost. He tried learning nonsense syllables with twenty-four repetitions at one time, then similar series with eight repetitions per day for three days, then four for six days, and finally two a day for twelve days. It was found when tested by the method of paired associates twenty-four hours after the last repetition, that the more the repetitions are divided, the greater the amount retained. Ebbinghaus had earlier compared greater numbers of repetitions. On one occasion he read a series of twelve syllables

68 times and found that twenty-four hours later he needed seven repetitions to relearn. Then he repeated another of the same length, 17½, 12, and 8½ times, a total of 38, and found but five repetitions were needed for relearning twenty-four hours later. Still later Miss Perkins[1] continued the extension of distributions. She compared accumulated repetitions of eight a day for two days, with four for four days and two for eight days, and one repetition per day for sixteen days, and with one every other day, every third, and every fourth day. The total repetitions were sixteen in each case. The distribution alone was different. The results were tested after fourteen days and proved even more striking than those of the earlier tests which were made after twenty-four hours. Eight repetitions a day for two days gave only from 9 to 17 per cent correct responses, and the larger number was obtained when three days were permitted to elapse between each series of eight repetitions. Four readings a day gave from 25 to 41 per cent, with larger values for the wider distribution of repetitions; two a day gave from 45 to 78 per cent, while a single repetition every day gave 79 per cent; a single repetition every other day, 72 per cent; every third day, 82 per cent; and every fourth day, 68 per cent. It would seem, then, that one repetition every second or third day is the best distribution for learning.

Advantages of Spaced Repetitions General. — On the whole, spaced repetitions have been proved to give better results with almost all types of learning than do massed repetitions. Acquirement of skill in typewriting, throwing at a target, running mazes have all been tested and, with few exceptions, intervals between periods of practice increase the effect of the practice period. Learning sense material is quite as much improved by spacing the repetitions as is learning nonsense material. Mrs. Austin found for sense material that the difference in favor of distributed repetitions increased with the interval between learning and recall. The difference was slight for tests after twenty-four hours while it was considerable at the end of a month. Opinions and results differ as to whether distribution is more advantageous early in the learning or later. All agree that under most conditions distributed or spaced learning gives better results for the time spent than does accumulated or massed learning.

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[1] N. L. Perkins, "The Value of Distributed Repetitions," *British Journ. of Psychology*, vol. 7, p. 253.

Explanation of Advantage for Spaced Repetitions. — An obvious explanation of the greater effect of spaced repetitions is that they bring the learner to the problem in a more rested condition and permit him to cease work before he is bored. More important, probably, is the series of facts developed by the experiments of Jost. He found that, when he compared the number of repetitions required to develop completely two sets of associates of equal strength but of different ages, the older set required fewer repetitions than the newer. His method was to learn one series of syllables twenty-four hours earlier and then to make a few repetitions of another series a few hours before the test. The amount retained was tested by the method of paired associates. When three times as many correct associates could be given from the newer series, it required almost the same number of repetitions to bring each to the point where it could be said through without mistake. When the number of correct associates that could be given was approximately the same for both series, the older series could be fully learned much more easily than the newer ones. His theory is that the associations continue to grow strong, to 'set,' for some time, perhaps for two or three days after they are first formed. The fact that with associations of equal strength but of different ages, the older associations can be completely learned with fewer repetitions than the younger has been designated "Jost's Law." In effect this means that, after each series of repetitions, the associations that are developed tend to increase in strength without further repetitions for two or three days. When the repetitions are divided, there is one of these setting periods after each series of repetitions. When they are accumulated, there is but one 'setting' for all. It is possible to connect this setting process with the continued activity, perseveration tendency, that constitutes the primary memory or immediate retention. This setting is one more expression of the inertia of the nervous system.

Several important practical deductions may readily be drawn from this law. Obviously, it connects well with the preceding law, since, if one is to learn as a whole, only short selections could be learned in any one day. Coupled with the advantage from divided repetitions, it gains full force, since, if the selection be not learned at the first sitting, it is an advantage to wait a day or two before proceeding to complete the learning. Again the bearing upon the familiar topic of cramming is quite evident. What is repeated often at periods considerable distances apart is learned thoroughly, while accumulated repetitions in a brief period produce slight effect and one that quickly disappears. This is more certain from the fact that divided repetitions leave much more persistent effects than accumulated. In general, the more the repetitions are divided, up to one every third day, the more permanent will be the learning.

Rate of Repetitions. — Other factors that affect learning are the rate at which the material is read and the degree of activity or the degree of attention given it. The rate of repetition has been several times investigated with slightly different results. Ebbinghaus first asserted that the more rapid the rate, the quicker the learning. Ogden modified this by showing that learning was quickest when reading was at the fastest rate possible without too much effort. Part of this difference lay in the fact that Ebbinghaus used the time alone as a measure of effectiveness; Ogden employed both time and the number of repetitions. Meumann, as a result of experience gained from many investigations, concludes that the best rate varies with the individual, the material to be learned, and the familiarity of the learner with the material. It is best to read relatively slowly at first when the subject matter is being understood, and more rapidly later, up to the point where the effort begins to distract.

Active Repetitions More Effective than Passive Ones. — The effect of the attention of the reader has been investigated numerically only in one respect, the advantage of active repetition as compared with passive reading. Witasek made experiments to determine the best combination of reading with attempts to repeat. He found that the most satisfactory result was obtained when he read five times and then repeated fifteen times from memory. Gates confirmed the results. Skaggs[1] found it most advantageous to read over six or eight times at first and then to alternate reading and attempted repetition from memory until learning was complete.

It is evident that attempting to repeat from memory requires more effort and will hold attention much more than passive reading. It should be said, however, that repeating material in an abstracted state, practically without attention, will give rise to learning in a much shorter time than one would think, although it is of course not so effective as repetition with full attention.

The Intention to Learn. — The effects of an intention to retain or of a knowledge that learning is desirable is a determining factor in retention and learning. If observers are induced to read lists of words or syllables by asking them to compare letters, or by any subterfuge that does not suggest later recall, it is shown that the material is much less likely to be learned than if it is read with the intent to learn. Meumann and others found a saving of 50 per cent or more if series were repeated with the expectation of being tested on them later, as compared with similar series that were learned without knowing that the learning was to be tested. Sanford[1] found almost no learning to result from the daily reading of the morning service without intention of recall, although he estimated that he had read the service five thousand times. There is some evidence, too, that intention to remember for a specific occasion makes the material learned persist up to that time only and be forgotten afterwards. This has its effect upon material crammed for a particular examination. The lawyer may for a few weeks when dealing with a case involving technical knowledge become an expert on that topic for the time, only to forget most of it as soon as the case is over. Mr. Meyer has evidence that preparing for an examination by the true and false statement method makes it possible for the student to pass such an examination without being able to recall the material for an ordinary essay type examination. They can recognize but not recall the material they have read.

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[1] Skaggs, *Journal of Experimental Psychology*, vol. 3, p. 424. Cf. Gates, "Recitation as a Factor in Memorizing," *Archives of Psychology*, no. 40.

Associative Inhibition. — An interesting fact in connection with learning is that if you have already made one connection with an idea or word, you cannot so readily connect another one with it as you could the first. This was first demonstrated experimentally by Müller and Schumann. They found that if they first learned one syllable in connection with a given one, and then attempted to learn a second with the same syllable, it required more repetitions than it did to learn the first. They demonstrated this by learning a series of syllables *a*, *d*, *g*, etc., first with *b*, *e*, *h*, etc., and then later *a* with *c*, *d* with *f*, *g* with *j*, etc. It was found that it took considerably longer to learn the series of syllables when other syllables had already been connected with them than when learned for the first time. In experiments, the syllables to be relearned were interspersed irregularly, so that the association with the old positions and with syllables, that were near but not contiguous in the first connections, should not aid in the relearning. Shepard and Fogelsonger extended the experiment to demonstrate that inhibitions developed when the common element in the pair was second instead of first. They also showed that, if the first member of the pair was compounded of two parts placed one above another and either the upper or the lower part was changed, it became more difficult to learn the pair than when all elements were kept exactly alike.

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[1] *Studies in Experimental Psychology,* Titchener volume, p. 5.

The effects of associative inhibition in everyday practice are numerous. If one makes a mistake in learning a statement for the first time, one will find it more difficult to learn the correct statement than if the mistake had not been made. Another application is in the learning of languages. The student is told that he should not begin two languages at the same time, which shows a popular appreciation of inhibition without reference to a knowledge of the experimental law. One element in learning a language by the textbook method is to connect the English word with its foreign equivalent. If the student is attempting to connect the English word with two equivalents in different languages, each inhibits the learning of the other. When one language has been well learned it helps rather than hinders the learning of a second. That no inhibition develops when the first connection has been made strong, has been shown experimentally. Bair found that if he tried to begin to learn two different typewriter keyboards at the same time, there was interference. If he tried to learn a different keyboard after he knew one thoroughly, it was easier to learn the second.

Uncompleted Tasks Remembered. — Zeigarnik showed that uncompleted tasks are remembered better than completed ones. She gave individuals a large number of small tasks. In some cases the tasks were completed without interruption. In others the worker was asked to stop and begin something else. After an interval the workers were asked to give a list of the tasks they had been working on. It proved that a larger proportion of the tasks that had not been finished were remembered, than of those that had been completed and put aside. The work was regarded as an indication that an open Gestalt showed greater stresses than a closed one. The uncompleted tasks constituted the open Gestalten.

FORGETTING

The laws of retention or of its complement, forgetting, are quite as important and as striking as are those of learning. If learning is the formation of associative bonds, retention is the persistence of those bonds, forgetting the weakening of the bonds that are formed in learning. Ebbinghaus first and Radossawljewitsch later made comprehensive experiments on the percentage of the learning effect that was lost after dif

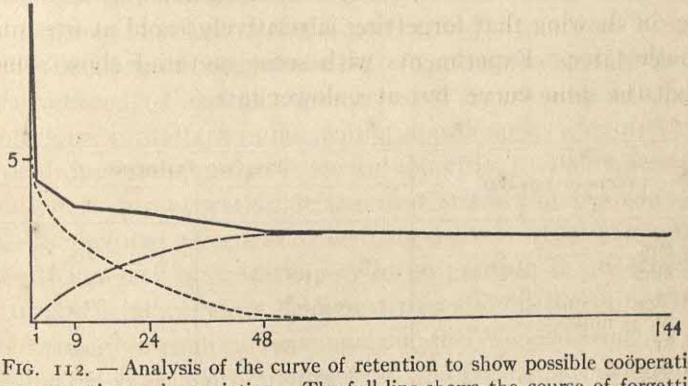

FIG. 112. — Analysis of the curve of retention to show possible coöperation of perseveration and association. The full line shows the course of forgetting after Ebbinghaus, the dotted line the conjectured decrease in the primary memory (perseveration), and the dashes the initial increase in the strength of association due to perseveration.

ferent intervals from five minutes to thirty days. The table gives in parallel columns the percentage of the number of repetitions required to relearn to the point where the series could be repeated once accurately, compared with the number required for the original learning. Two striking differences may be noted. Ebbinghaus found larger percentages forgotten in the shorter periods. He also found a regular decrease over the second day as compared with the late readings on the same day. Radossawljewitsch's results indicate that the subject required fewer repetitions to relearn after twenty-four and forty-eight hours, and even after six days, than after eight hours. This means that he learned better in the morning when fresh than in the evening, and that this more than compensated for the greater time. The results agree, apart from this difference between morning and evening learning, in showing that forgetting is relatively rapid at first and slower later. Experiments with sense material show somewhat the same curve, but at a slower rate.

LENGTH OF INTERVAL	PER CENT FORGOTTEN	
	E	R
5 min.		2.5
20 min.	41.8	11.4
1 hr.	55.8	29.3
8 hr. 45 min.	64.2	
8 hr.		52.6
1 day	66.3	32.2
2 days	72.2	39.1
6 days	74.6	50.7
30 days	78.9	79.8
120 days		97.2

Reminiscence and Oblivescence. — Ballard, and Nicolai and Williams after him, have shown that not in all cases is there an immediate loss in the material that is learned. On the contrary, occasionally the capacity for reproducing what has been learned may increase at first and only later begin to decrease. Ballard called this apparent improvement in capacity for repetition with the age of material, reminiscence, and opposed it to the more usual oblivescence. It is shown by the fact that an individual may be able to recall 10 per cent more of a poem four or five days after learning than he could immediately after completing the learning. Ability to recall attains a peak two to six days after learning and then falls off gradually. The results are not all in harmony as the conditions and materials that favor reminiscence vary. Ballard thought it was restricted to children under twelve. It has been found in adults, if more rarely than in children. Reminiscence is also more prominent in partly learned material. The phenomenon, too, is more likely to show itself in sense material than in nonsense. Some workers seem to find it more general in the duller children.

Explanation of Reminiscence. — Various suggestions have been offered to explain reminiscence. One of the first was suggested by Ballard as due to the consolidation of the effects of learning in the period following repetition. This would be due to the perseveration or the continuation of the activity of the neurones after the repetitions cease. If we recall that eidetic imagery is present in children and not in adults and that eidetic imagery can be regarded as a vivid continuance of the primary memory, perseveration, this would explain why reminiscence is more frequent in children than in adults. It has also been suggested, if reminiscence is connected with under-learning, that children probably are more given to under-learning than adults, which would also explain the greater frequency in children.

Forgetting of Classroom Material. — The student must be struck with the small amount of retention after a month. Ebbinghaus and Radossawljewitsch both found that little over 20 per cent of the effects of learning persisted after thirty days. Sense material remembered for meaning alone shows a better performance, although even here the amount retained is disappointingly small. Greene made a series of retests of students by giving them the same short form examination in the fall that they had taken in June. Classes were tested in psychology, zoölogy, and physiological chemistry. There were some in the fall tests who had taken the course earlier than the spring semester which gave an approximate curve for retention for longer periods. As will be seen from the table below, the curve shows the same rapid forgetting for the earlier period and more gradual falling off over the longer periods as for nonsense syllables. The proportion of the whole forgotten is not so great. Less than half of what was learned was forgotten in the three-month interval. Johnson found similar results for botany. This test with an examination is more severe than the relearning test, since it requires an actual reproduction. Were one to measure a student by the amount of time needed to bring the grades in a course back to those made at the first examination, the loss would be found to be very much less striking. What is retained from a course are the more important principles and an ability to relearn much more quickly.

FORGETTING IN COLLEGE SUBJECTS

	ZOÖLOGY	PSYCHOLOGY	PHYSICAL CHEMISTRY
Score on June test	76	70	80
Score after 4 months . . .	42	42	48
Score after 8 months . . .	44	26	
Score after 16 months . .	37	25	
Score after 20 months . .	32	24	

Retroactive Inhibition. — The one factor in any degree subject to control which has been shown to influence retention is the activity which follows immediately upon learning.

Müller and Schumann first observed that if one turned immediately after completing the learning of one series of syllables to learning a second series, less of the first series was retained than if one rested for a time after the learning. They called the effect of learning the second series to reduce the retention of the first retroactive inhibition. The effect has been demonstrated by most experimenters, but at least two theories have been advanced to explain it. Müller ascribed it to the interference of any activity with the perseveration process. He found that the disturbance was just as great when the subject was active in other kinds of mental work as when he learned other groups of syllables. A second explanation assigns the cause to a form of associative inhibition between the first series learned and the second. To test this hypothesis, experiments have been made to determine whether the degree of similarity between the series learned would have any effect upon the amount of retroaction. Where the material learned later is identical with the original, there is of course just more learning and no inhibition. The effect of inhibition is greatest when there is a medium degree of similarity. When the two series are altogether different, less hindrance to learning is noticed than when there is a moderate degree of similarity. These tests cannot be regarded as proving which is the more plausible theory. Probably both effects coöperate in some degree.

To produce the greatest decrease in retention, the interpolated work must come fairly soon. Müller asserted that it must come within six minutes, the period during which immediate or primary memory lasts. The material, too, must be not too well learned. The more completely established is the material, the less the retroaction. If we are dealing in part with an interference with the primary memory or perseveration, the effect would be analogous to what the psychiatrist calls retroactive amnesia, a forgetting that runs backward from the inciting cause. If a football player is struck on the head and rendered unconscious, he is likely to be unable to recall all the memories that have not yet become organized. The last event he may remember would be going to the field. The events of the game would be entirely forgotten. Similarly any mental activity is supposed to inhibit the retention of connections which have not been fully organized or set.

The Effects of Sleep and Waking on Forgetting. — If activity following learning disturbs the retention, it should follow that the best retention would go with the minimum activity. Dallenbach and Jenkins tested the hypothesis by comparing the retention when the learner went to sleep immediately after learning, with that when he was awake for a corresponding time. The results indicated that there is little loss during sleep. In the experiments the subject was tested after one, two, six, and eight hours' sleep. It was shown that there was a loss of material after the one- and two-hour periods, but little after the six- and eight-hour intervals. The result is complicated by the degree of recovery from fatigue and particularly by the fact that after one and two hours it was almost impossible to waken the sleeper completely. In some cases, the man did not remember in the morning that he had been tested. These results and van Ormer's seem to prove that forgetting almost stops during the sleeping period. This would also aid in explaining the decrease in forgetting shown by Radossawljewitsch's subjects after twenty-four hours, when the intervening night had been spent in sleep.

Is Forgetting Ever Complete? — It is evident from these studies that associations persist when there is little immediate awareness of them, when one associate cannot be brought back by another closely connected with it; when the associations can be detected only from the fact that they may be reëstablished more easily than if they had not previously been formed. This fact has given rise to much discussion as tc whether anything is ever forgotten. The discussion arose originally from the fact that occasionally long-forgotten events from a remote past are recalled. Coleridge cites the case of a girl, a servant in the house of a pastor, who was accustomed to walk up and down a passageway near the kitchen where she was employed reciting passages from Greek, Latin, and Hebrew authors. Some years later in a delirium of fever she was heard to recite strange words that convinced her attendants that she was possessed of a devil. The physician wrote them down and traced them to works in the possession of the old pastor, now some years dead. If the case is to be accepted, memories that never were consciously developed, and which should have been forgotten if they ever had been developed, may still be lying dormant in the nervous system. Numerous other cases may be cited of the return of experiences long forgotten, usually in the case of disease, under hypnosis, or in similar abnormal conditions. These cannot be taken to prove the thesis for which they are adduced, but they may serve to reënforce the statement that experiences leave their effect for some time after they can no longer be recalled through associations of ordinary strength. Not improbably the nervous system never altogether loses some trace of them. This fact is of more importance in explaining recognition, the control of belief, and similar processes, in understanding which we must appeal to the effect of experiences not definitely conscious at the moment, than as a contribution to the understanding of retention and recall. Memories constantly grow weaker at a rate that depends upon their meaning and interest, and gradually, if not refreshed, reach the stage at which they cannot be revived.

RECALL

The real criterion of all learning and of retention is the possibility of recall. Relearning may prove that what has once been learned still persists when one cannot immediately recall it, but relearning itself is in turn tested by the possibility of recall even if the recall be only a brief period after the last repetition.

Recall, as was seen in Chapter XI, is always through association under the control of the wider purpose of the moment and of other less conscious factors that constitute the mental attitude or context. To recall any old event it is necessary to have an idea which is in some way connected with that event or has some element in common with it. If we assume the possession of a definite memory with a large number of connections, some one of the connections must become conscious before the memory itself will make its appearance. Usually the desire to remember is either itself an associate of the memory desired or both are connected with a common idea. Thus, when one is asked a question in an examination, the question has been connected with the answer and serves or should serve to recall it. The course of the association is determined by the setting; the context of the question is supplied by the subject in which the examination is held. In practical life the occasion for the recall is a need for the bit of knowledge. A face presents itself and one knows that the name will be needed when it becomes necessary to make an introduction; or one is reading of the size of a ship in meters and wonders how long it is in feet, and must recall the table of equivalents. In each case there is always something that makes it desirable to know the thing to be recalled, and this has also been associated with the fact. Not all associates of an idea are actually recalled. The reason for this is usually that the right context is lacking. One may read of the length of the ship in comparison with other ships whose lengths are also given in meters, and as relative size is all that is necessary, the thought of the equivalent does not present itself. The mental attitude or need of the moment is always dominant.

Reproductive Inhibition. — A complement and necessary consequence of associative inhibition, discussed on pages 495 f., is reproductive inhibition. When one term is learned with two other terms, we saw that learning with the second required a longer time or more repetitions than learning it with the first term. Reproductive inhibition designates the fact that after the term has been learned with the two others, to recall either term when the first is given requires a longer time and the recall is less likely than if the term has been learned with but one of the others. This reproductive inhibition is probably the explanation of those painful if rather unusual instances in which one has occasion for a fact, is sure that it is known, perhaps well known, but, do one's best, cannot recall it. One may be asked the name of a famous painter, and find to one's astonishment that it cannot be recalled, torture one's memory for it as one may. Frequently after the occasion for it has passed, it will come back without the least difficulty, often when thinking of something entirely different.

Müller and Schumann demonstrated the presence of reproductive inhibition when the two different syllables succeeded the common one. Shepard and Fogelsonger showed that it was present also when the common syllable followed the two with which it was linked.

The explanation of the instances in everyday life, in which one is sure that one knows a fact and still it will not come, is probably to be found in a mutual checking of each other by the associates that are contending for the mastery. It is probably a true positive inhibition of the kind that we know to exist between reflexes. The activity of one path serves to prevent the activity of the other. Reproductive like associative inhibition is most evident between two connections that are relatively weak. Bair's experiments on the typewriter prove for the recall as for the learning that, if the first keyboard had been thoroughly mastered, a second would be learned more quickly than was the first, and later no difficulty would be shown in using either. Were this not true, there would always be interference. A blocking of recall would be much more frequent than we find it, since practically every bit of knowledge has many associates that might interfere. The effect of the purpose or attitude is usually sufficient to prevent inhibition. When the context favors one associate much more than another, the way is cleared for it and all others are kept from interfering. Interference comes when the associations are not fully formed, are relatively weak, or no strong purpose is dominant.

RECOGNITION

The Place of Recognition. — In our studies of learning a movement, it was emphasized that two parts must be distinguished. These are, first, making the movement originally and, secondly, accepting the movement or its results as satisfactory. Approximately the same two aspects of a common process are to be distinguished in mental acquisition and especially in the recall of what has been learned. When an experience presents itself as an answer to a question that is asked or with the claim to come from a definite time in the past, it must be passed upon before it is accepted as true or as having originated at the time asserted or assumed. This acceptance is due in large part to the forces which determine the recall. Usually the material suggested is accepted immediately. Sometimes, however, several suggestions will present themselves before one will be accepted as fulfilling the conditions. The process of accepting the returned impressions and of dating the time of their original appearance is what we call recognition. Recall provides the material in memory; recognition is the process of accepting or rejecting. It affirms or denies in part by assigning a date, — by referring the experience to the time and place of its original appearance. This is in itself a warrant for the truth of the recalled process. Thus in an examination many ideas may be suggested, one after another, as the answer to a question of fact. If questioned, it is usually not until the idea can be assigned to a particular book or to a particular lecture that it will be accepted as sufficiently assured. Recall must be tested and confirmed by recognition before memory is complete.

The Process of Recognition. — Recognition applies to objects as well as to ideas or memories, and may be studied equally well with one or the other. When one sees a person, one must decide whether he is an acquaintance or a stranger before one speaks; and if he proves to be an acquaintance and he approaches, it is convenient to know his name and where he was seen before. The process of recognition may in itself be nothing more than the arousal by association of his name or of the place where he was last seen, or of the topic discussed with him at the last meeting. When these associates present themselves, recognition is completed. The explicitness of the recognition depends upon the definiteness of the associations that come to cluster about the face. Memories are recognized in much the same way. When the idea is recalled, secondary ideas are aroused which give the first a setting and a warrant.

An objective study of the phenomena of recognition adds much that must be considered in any theory. As compared with recall, recognition is as a rule easier and is induced by fewer repetitions. A student will frequently recognize an answer when given by another in a recitation, after he has himself failed. It is easier to learn nonsense syllables to the point where they may be recognized when shown than to the point where they may be repeated. On the other hand, one frequently finds in pathological cases that recognition is disturbed while recall is still almost unimpaired. This is often seen in psychasthenia. The psychasthenic at times will find everything strange, at other times will recognize objects and people that have never been seen before. Everything seems strangely familiar to the patient. Apparently recognition is a rather more certain process than recall in the normal individual, but is more easily disturbed in the abnormal; in fact it is often the first process to be disturbed in mental deterioration. It is also less affected by work performed after the learning — by retroactive inhibition — than is recall. In some ways, then, it seems more easy to induce recognition than recall, but at the same time recognition is more delicate as measured by the susceptibility to impairment by disease. Again recognition is not so readily disturbed by mental work immediately following as is recall.

Experimental Studies of Recognition. — Experiments were early made and have been frequently repeated on the effects of the passage of time upon the accuracy of recognition. The results fall into two distinct classes which may be represented by two of the earliest workers, Wolfe and Lehmann. Both sought to determine the influence of the lapse of time upon the accuracy of recognition. Wolfe[1] worked with tones which could be made to differ by as little as four vibrations, and had a number of tones at his command, so that they could not be readily referred to a class or given a distinguishing name. He found that capacity to recognize diminished with the passage of time, at almost the same rate as the ability to recall. His curve showed the same form as Ebbinghaus' curve of forgetting; recognition fell off rapidly at first and much more slowly later. Lehmann[2] used gray papers of different shades. At first he used five shades. His subjects at once arranged these in a series and gave a definite name to each. His results showed almost no tendency to diminution of accuracy with the passage of time. At first the judgments increased slightly in accuracy and then declined slightly, but there was no approach to the logarithmic curve obtained by Ebbinghaus. When Lehmann introduced nine shades, these were given numbers from one to nine, and the curve retained the same form. Later investigations by Angell and Hayward[1] and by Hayden[2] under approximately the same conditions have given results similar to Lehmann's. The difference in the results obtained by Wolfe and the others may be attributed to the degree in which the material makes possible the association of a word or other familiar symbol. The word or symbol acts much as the type or concept as discussed in Chapter XIII. When it appears, it constitutes a point of reference. It is itself at once familiar and seems to be part of the old knowledge. The word as a concept passes on the familiarity and accepted certainty of knowledge which itself possesses to the qualities to which it is ascribed. It acts in the same way that an accepted principle in a science acts in confirming some new observation. When the new observation can be seen to be an illustration of the established law, it is itself both accepted as true and can be more readily remembered.

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[1] Wolfe, *Philosophische Studien*, vol. 3, p. 534.

[2] Lehmann, *Philosophische Studien*, vol. 5, p. 96.

This difference between the results obtained by Wolfe and those obtained by the others is similar to the difference between results with nonsense and sense material. A number of recent experiments by Hollingworth, Miss Mulhall, Strong, and others showed the same difference in ease of recognition between material that has and that which has not meaning. They found in the first place that recognition was much more certain and persisted longer with meaningful material than with nonsense syllables. Recognition was from two to three times as accurate as recall when advertisements, pictures, words, or other sense material was used. But with nonsense syllables, recognition had very little if any advantage over recall. If we apply this to our other problem, it is evident that recognition of meaningful material has a very great advantage over recognition of nonsense material. In the one case the shades of gray could be immediately connected with words that either had a definite meaning acquired long before the experiments were begun, or that could be quickly developed for the few shades used. One association alone needed to be formed in order to assure recognition in each experiment. Recognition itself required no more than a decision whether the shade offered did or did not correspond to the standard required. In Wolfe's experiments, no standards were present at the beginning and none could be readily developed because of the great number of tones used, and the slight differences in pitch that were available. Here one dealt with bare association processes formed during the experiments between sensations, neither of which had a meaning of its own. All the preparation for recognition must be made during the experiment, while in the experiments with meaningful material, most of the preparation was completed before the experiments were begun. Meaning, then, contributes much to the ease and persistence of recognition.

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[1] Angell and Hayward, *American Journal of Psychology*, vol. 11, p. 67.

[2] Hayden, *American Journal of Psychology*, vol. 17, p. 497.

Forms of Recognition. — Investigators have classified forms of recognition as definite and indefinite, explicit and implicit. We may regard as complete recognition a feeling of assurance as to the place where the object was seen before, and a recall of all the circumstances of that earlier experience. This is called definite as opposed to indefinite recognition. In indefinite recognition one is aware that the thing is familiar but can assign no definite place to it. Many faces are familiar which arouse no name, and cannot even be referred to a specific time or place. This indefinite recognition is ordinarily due to slight familiarity. Implicit recognition stands, in degree of familiarity, at the other extreme. Things which are very familiar are also recognized, but, because of their great familiarity, are referred to no definite place. Here the familiarity is taken for granted. This happens with the furniture of a well-known room, with intimate friends, and with events that are frequently recalled. Implicit is opposed in definiteness to explicit recognition. The objects presented are treated as if known, arouse a feeling that is different from that aroused by strange objects, but are seldom referred to earlier times or even named.

Still another distinction must be drawn with reference to awareness of cause of the recognition. In certain instances one can see how the recognition is accomplished. A hauntingly familiar memory makes its appearance, but it has no connections and can be given no place. Gradually, as one broods over it, other things are called up by it. Then suddenly an associate, itself familiar, is added to it, and recognition is complete. This may be called mediate recognition, as opposed to the immediate recognition which is much more usual. As will be seen, all of these types have common laws. Those mentioned later are reductions from the complete form.

The Association Theory of Recognition. — Theories of recognition are very numerous and in some degree conflicting. One has been already indicated, the placing of the unknown through association with the known. This can be traced empirically very frequently. One hears the title of a book; it sounds familiar, but can be given no place. Gradually, ideas cluster about it until it is placed as a novel by such an author, read on the boat two years ago; or it may be remembered as the book that was recommended by Jones but which has not been read. Similarly with the recognition of objects. This bit of crystal at first seems to be absolutely unknown; then a background grows up about it; you remember where it came from; that supplies the name and the purpose for which you obtained it, and the whole recognition is complete. The association theory assumes that all recognition is of this type, and that in the cases in which the recognition is indefinite, the associates are present and have their effect, although they are overlooked or do not come to full consciousness. They nevertheless provide the mark of familiarity, give a color to consciousness that is accepted as a warrant for the belief that the idea or object has been experienced before. Miss Wylie and others who have experimented with recognition assert that the observers report associations, as occasions for recognizing, more often than any other specific criterion.

Unnoticed Associates May Induce Recognition. — Even in immediate recognition the associations give the quality of familiarity. Probably the feeling of familiarity is due in the case of these very frequently repeated objects and events to partially open association paths that give recognition without any definite recall of the associated events. When the object is familiar but cannot be definitely placed, it is probable that there are also partially open association paths, but that they do not lead to the meaningful object or to the fixed landmark. The feeling is present with nothing to fix the experience. Similarly, in certain cases in which the recognition is false, when one sees an individual who seems familiar but on speaking finds that he is not an acquaintance, it is probable that something in the person suggests another or calls up associates that are misplaced. Here the associates give the feeling without any warrant in fact. In short, partially open association paths give the feeling of familiarity when recognition is not complete and even when the recognition is not objectively true.

The Motor Theory. — Another theory with many adherents is that the feeling of familiarity comes from slight movements awakened by the stimulus or image. This is approximately the same theory as the other, except that the processes aroused are first motor, then sensory. The idea arouses some habitual movement, slight or more intense, and this constitutes the basis of the assurance that the object has been seen before.

The movements certainly are not noticed for themselves, but because of their arousal, the familiarity attaches at once to the object. The best instance of this is to be found in the feeling of 'at homeness' that comes with the use of an old tool or instrument when one handles it after a long period, as compared with the feeling of a strange one, even if it is of the same pattern. The habits that have been developed in its use are suited to it, and the pleasant feeling of familiarity results.

The Feeling Theory of Recognition. — Another group of theories starts with the assumption that recognition is an immediate experience which cannot be analyzed or explained, but must either be accepted as a given fact or be speculated about in general terms. The more definite of these theories asserts that recognition arises because of the pleasure which attaches to the familiar experience, as compared with the unpleasantness or neutral quality of the unknown. The pleasure is explained as the result of an instinct. The known is pleasant, since one always makes an immediate response to it. If harmful, one can avoid it immediately; if beneficial, it is pleasant in and of itself. The objection to the theory is based primarily on fact. Not all cases of recognition are pleasant, certainly not all pleasant things are familiar. Another theory in this group asserts that familiarity is an immediate conscious experience, even more primary than either sensation or association. This theory presents a possible interpretation, if all others fail. The same objections hold against it as those raised against nativism in space. It gives up the problem without attempting an explanation.

The Advantages of the Association Theory. — The evidence so far accumulated favors the association theory in some form. Indirect recognition can be traced to associations. In direct or immediate recognition, we cannot detect associations explicitly. Nevertheless, three facts indicate that they must be present. (1) Things that have many associates are readily recognized, while nonsense material — that is, material without associates — is recognized with difficulty, is recognized little more easily than it is remembered. Recognition is aided also by two of the factors that aid association. (2) Meyer showed that recognition of nonsense syllables was more accurate when a syllable with which it had previously been associated was shown, just before the syllable to be recognized was presented. (3) It has been proven, too, that recognition is quicker and more accurate if the individual is in the proper attitude toward the object to be recognized before it is shown. Just as in everyday life, if one meet an old acquaintance, when one has been thinking about the place where he was known, one is very much more likely to recognize him than if he appears without any preparation. These facts together indicate that association and recognition are very closely related. Recognition always comes when associates are aroused; and, where associates are not overtly present, experiments indicate that conditions which favor the formation of associates or recall by association also favor recognition.

Meaning and Recognition. — In any statement of the association theory of recognition, it is taken for granted that the associates must be themselves familiar or the process will not be complete. Sometimes several links are necessary before a familiar associate presents itself. The familiarity, that attaches in turn to the associates effective for recognition and also to the objects recognized immediately, is itself due to associates. The difference between the mediate and the immediate is another expression of the difference between the two sorts of recognition that distinguished the methods used by Wolfe and by Lehmann. In Lehmann's form the new is related to some established type, to something that has been used so frequently and recalled so often that it has become firmly established and thoroughly familiar. These are accepted at once and without question. They are the types or concepts which were discussed in Chapter XIII. These fixed types are themselves established by the numerous uses that have been made of them. They, too, are recognized or accepted because of the numerous connections that have been made with them in the past. These connections tend to arouse specific ideas, but they do not completely arouse them. The partly aroused ideas give the certainty of recognition. Your own name, to take an extreme case, is established more firmly in your mind than the name of another, because of the number of times it has been associated with yourself and with other experiences. Certain events become landmarks in all memory and may be used as points of reference because of the number of associates that have been made with them, and through their frequent recall in different connections. When an event that is at first unplaced can be attached to one of these firmly established incidents, it at once takes on something of its familiarity, in the same way that assignment of the name was all that was necessary in Lehmann's experiments to constitute recognition of the shade.

Recognition and Cognition. — Recognition is largely aided by the types that were found so important in perception, and also by meaning, a process fundamental to thinking of all sorts. The function of the type and of meaning may be seen more clearly in the more general form of acceptance of an object, cognition. Here objects are referred to classes rather than to particular times or places. Cognition is more frequent than recognition. We are constantly referring all objects that come under our notice to a class. Natural objects are named, tools related to their uses, people are assigned to different races or classes when they are not acquaintances. This process of cognition differs from recognition only in that there is no reference to the earlier experience of the individual, no awareness that the thing has ever before been seen. Except for determining ownership of objects and for our relations with people, it is seldom that we need to do more than cognize. Cognition differs from recognition solely in that the reference is to some class only, some type of objects, with no reference to personal knowledge. The process involves the same factors; a general notion always serves as the point of attachment, but this has a more or less marked series of associations that irradiate from it to give appreciation of its use, or of its special characteristics. In almost every respect it is like the type or concept which we saw to be evoked in perception, and which constitutes what we accept as the real object. Cognition is a reference of the particular object or memory image to a similar typical object or class. Memory is like perception in that it deals with real objects or concepts, rather than with mere centrally aroused sensations.

MEANING AN AID TO MEMORY

Meaning in Learning. — Meaning is not only a factor in making recognition possible but is also important in all learning. The meaning that the material to be learned has for the individual determines in very large degree how quickly it may be learned and how long it shall be retained. The difference in the amount of time required for learning and the degree of retention between sense and nonsense material is very striking. This may be seen both in primary memory and in learning long series. Ebbinghaus found that school children could give only five of seven nonsense syllables, while, given a sentence of 38 words containing seventeen separate ideas, they could remember fifteen of the ideas. For himself he found that with the same number of repetitions he could remember eight or nine times as great a quantity of simple poetry as of nonsense syllables. Meumann obtained slightly smaller values, 7–9 nonsense syllables, 13 words or numbers, 20 words of a poem, and 24 of philosophical prose.

Meaning not only aids in learning but also assures a greater persistence of the material that is learned. The material learned is much less readily forgotten. Ebbinghaus demonstrated the fact for rote memory of verse. In some of his earlier experiments he used a translation of Byron's "Don Juan." After twenty-two years, he found that he could detect a saving of 7 per cent in the time required for relearning stanzas as compared with learning new stanzas. After seventeen years there was a saving of 20 per cent in relearning stanzas which had originally been learned on four successive days. This is to be compared with a saving of 20 per cent for nonsense syllables at the end of thirty days. The retention of ideas is still more complete. General principles, or even interesting events, are frequently recalled after the greater part of a lifetime. Here, however, there is usually repetition or recall in the intervening years.

Meaning Due to Grouping and to Reference to Systems of Experiences. — Two reasons may be found for the greater ease of learning meaningful material. First, that to gain meaning the different partial experiences must be grouped about a single center, must be combined into units, and these units are then remembered practically as single elements. In some recent investigations of a lightning calculator, Dr. Rückle, G. E. Müller found that an essential element of his ability to make calculations very quickly was his capacity for remembering figures, and that this in turn was due to an ability to unite the figures into small groups. Rückle could retain and repeat in any order forty-nine digits. He saw them arranged in seven columns of seven digits each. The seven series seemed to count for him as seven single units. A second element in acquiring meaning, well illustrated by this same investigation, is the attachment of the thing to be remembered to elements of experience already firmly fixed, — an interpretation in the light of old knowledge. Rückle related many of the numbers that he could remember to combinations of numbers with which he was already familiar. Thus he remembered 451,697, because it was made up of the multiples of two prime numbers: 451 = 11 × 41, 697 = 17 × 41. Six hundred and twenty-four was easy, since it is the square of 25 minus 1.[1] Large acquaintance with numbers made learning new ones relatively easy. All material that has meaning has these two qualities. It is combined into relatively small groups. These groups are used over and over again until they constitute a unit for practice and they are learned in different connections until firmly established and then can be recalled by many other experiences.

When anything has meaning, it is already connected with something that is a part of the fundamental intellectual equipment of the individual. In this, to have meaning and to be recognized or cognized are approximately identical. Thus we found that recognition consisted in attaching to the object or idea that is to be recognized some mark in itself familiar. The permanency of recognition, then, becomes the permanency of the older acquirement. In learning material that has meaning, the same factor is even more prominent. When the meaning of anything is understood, it is by that very fact united to the already familiar, becomes an instance under a general law or a general class, and that permits it to partake of the permanence of the general law. The meaningful material has meaning in part by virtue of the fact that it belongs to a larger group, and the reference to the larger group makes it easier to learn. This connection with what is already known makes it easier to understand and also makes learning quicker since the part is already known. These two characteristics alone would go far to explain the greater ease of acquiring sense material.

The importance of meaning can be seen to still better advantage in the form of learning most frequently practiced in adult life, learning the substance without the words. In this there must be some connection with a wider knowledge, or nothing can be retained. Almost anything that is understood can be retained for a little time, and to understand is, in essence, to connect the new with the previously organized knowledge. The degree of retention depends in part upon frequency of repetition of the ideas, but much more upon the number of different ways in which the new is linked with the old, and thus upon the completeness with which it is understood. While the process of understanding is more important on the whole than the formation of discrete associations, both must be present in some degree. Meaning has a basis in association, as has been pointed out, and, on the other hand, frequent repetition, even of nonsense syllables, tends to give them some meaning, however slight. For practical purposes learning sense or meaningful material and learning rote material are usually opposed. In rote learning, only the associates between the elements are considered; in sense material, the connections with the more general knowledge are emphasized. When one is learning by rote, the meaning of the material may be lost sight of; in sense learning, the words may be altogether neglected. Either form of learning can be trained at the expense of the other. Individual differences in the use of one or the other are matters of training, and it is possible to acquire the ability to use either at will.

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[1] *Zeitschrift f. Psychologie, Ergänzungsbd.*, vol. v, pp. 215 ff.

Memory and Gestalt. — Many of the rules that have been given for learning and recognition suggest problems of Gestalt. If a Gestalt is a process of organization that leads beyond the simpler units, many of the statements that have been made suggest this organization. The phenomena of associative and reproductive inhibition, as indication of the tendency of one whole to interfere with another, have been made much of by the supporters of the Gestalt theory. The value of meaning in learning and retention would also be indicative of the importance of organization. Recognition as an indication of the value of related experience in the appreciation of any single part would also fit into the picture. The fact that a Gestalt does not involve association, and that earlier experience is assumed to have no effect upon the development of the organization, markedly limits the applications of the Gestalt doctrine to memory problems.

GENERAL ASPECTS OF MEMORY

Individual Differences in Memory. — Not merely is there a difference in the degree to which rote and sense memory may be used, but there are differences in the capacity of learning in general and in the aptitude for learning different kinds of material. One of the most discussed is the difference between quick and slow learners. Popularly, it is believed that there is a law of compensation in learning in that, if one learns slowly, one also forgets slowly. Early experiments cited to prove the statement show only that there is a greater percentage of saving for the slower learners, but the number of repetitions required for relearning is least with the quick learner, and not so very much greater for those who learned more slowly in the beginning. Later experiments indicate that the quick learner is more effective in every respect. At the best, then, the slow learner has an advantage only in the percentage of repetitions saved, not in the amount that may be recalled by associates or in the time required for relearning. In several of the cases given, a quick learner would learn and relearn twenty-four hours later in fewer repetitions than the slow learner required for the first learning.

Dependence upon Age. — The dependence of memory upon age is fairly well established. Measured by either the memory span, or the quickness of learning, or the immediate retention, memory increases gradually to thirteen, then improves very rapidly to sixteen, and then more slowly to a maximum at twenty-two to twenty-five. From the maximum capacity there is a relatively slow decrease in the ability to learn until the age of forty-five and then a more rapid decrease. Thorndike estimates that there is a lessening in learning ability of about 15 per cent by forty-five. The results for the later period show wide individual variations. One man at ninety-one committed the Lord's Prayer in Swedish, a language with which he was not familiar, in half an hour. The aged have more difficulty learning nonsense material and material opposed to their habits, than they do sense material. Memory for material learned in the earlier years persists much better relatively than does the capacity for learning new material.

Children, on the contrary, are better able to retain the material they learn than they are to learn new. They retain the new knowledge rather better than adults, a fact which accounts for the large percentage of our memories derived from early childhood; but both immediate memory or memory span and ease of learning are greatest after maturity has been attained. Another factor that may be regarded on the whole as an individual difference, although it may depend upon habit, is the tendency to remember meanings or to remember by rote. This accounts for part of the apparent advantage of children. They are accustomed to learn by rote, and for that reason do it relatively better than do adults, who are at once lost in the meaning, and find difficulty in forcing themselves to attend to the words. The power of rote learning can of course be cultivated, and adults who have cultivated rote learning have an advantage in this also.

Dependence upon Types of Imagery. — Still another more truly individual characteristic is to be found in the dependence of memory upon sensorial type. An individual of a visual type is probably more successful in remembering words, colors, landscapes, and similar material; an individual of the auditory type, in remembering musical selections of all sorts, and the order of material that is learned. Which type is absolutely the best is not known, since investigations have not extended to a sufficiently large number of individuals. Meumann asserts that the visual memory is best for the retention of the elements, but that the motor-auditory obtains a more accurate grasp of the whole. In the work of the arithmetical prodigies or lightning calculators, differences in memory type play a considerable part in determining the character of their feats. Two that have been studied, Diamandi and Dr. Rückle, were visual in type, and one, Inaudi, was auditory-motor. The motor type did not lend itself to the reversal of operations, but with simpler processes was much quicker than the visual. On the whole the motor memory was quicker as far as it went, but much less flexible than the visual memory. When space factors entered, the visual far outstripped the motor-auditory. These are but illustrations of differences in capacity that depend upon the memory type.

Economy of Memory. — If one be asked how to learn to the best advantage, or how to improve one's memory or capacity for remembering, the best answer is to apply the rules given under the different heads of this chapter. If material is to be learned by rote, it is essential that there should be a large number of repetitions. In any case the repetitions should be divided over as many days as possible and should be made by the whole method, and not part by part or bit by bit. The units should be grouped into wholes as far as possible, since this grouping reduces the work that must be done in learning. Above all, however, wherever the material to be learned has any meaning, it is essential to understand it. Material understood is more than half learned. In the process of understanding, it is well to approach the material from as many different points of view as possible. The greater the number of points of attachment, the more thorough is the understanding, and also the greater the number of connections by which to arouse the memory in recall. Where matter is to be learned by rote as well as in substance, it is well to make two or three repetitions to understand the material, and then to proceed to commit to memory by repetition. It is essential also to attempt to repeat unaided as soon as possible. Usually after four or five repetitions, a free recall should be begun and frequent tests made of the parts that are least well recalled.

Memory Systems. — Numerous attempts have been made since classical times to develop methods of aiding memory. Latin orators made use of the device of picturing their orations upon the walls of different rooms of a house, one part on each wall of a room, and larger units in the same room. As they proceeded, they would picture themselves as walking through the house and reading their various headings from the walls. A more modern form of mnemonics, but one that goes back several centuries, consists in forming series of links, based upon chance associates between any two things that are to be recalled together. Thus one may remember that △ is the Greek letter Delta by the series: triangle, pyramid, Nile, Delta. Or it may be remembered that Denver is the capital of Colorado through the lingo, Colorado, dodo, bird, dense air, Denver. Similar connections are made by these systems between any two facts that are to be connected. Obviously any scheme of this kind will, in the long run, prove more harmful than helpful as it involves making four or five associates where only one is needed, and the others are likely to develop inhibitions as well as waste time. It is much better to trust to forming the associations directly, and better still, if connections are needed, to base them upon some fundamental general principle. The system of the sciences is from one point of view merely a vast mnemonic system, a means of bringing a large number of isolated facts into connection with each other in some logical way. To make use of that as a means of remembering is to follow a plan that has been developed by the best minds of all times, rather than some chance scheme that has been hit upon by a charlatan.

Memory Training. — A question of great practical as well as of theoretical interest is whether practice in learning improves the capacity for learning, and whether the effects of the practice extend to material of all sorts or are restricted to the particular kind of material that was learned in the training. There is no question that great improvement in learning a given sort of material comes with practice. Twenty hours of practice learning nonsense syllables will reduce by half or more the time required to learn a series of other syllables. Whether practice on nonsense syllables will reduce the time required for learning poetry is more open to discussion. Numerous experiments have been devoted to the topic. Meumann first tried testing individuals with one type of material, then had them practice on another kind, and then learn a second sample of the first kind. He obtained positive results. Dearborn suspected that part of Meumann's effect might be due to the preliminary test. To eliminate that effect he had a second control set of learners who took the tests alone without the training. They showed improvement, but not so much as those who were trained.

Woodrow repeated the experiment and added a third group who were instructed in methods of learning as well as given practice. This was done to test the theory that the improvement was due to acquisition of habits and not to improving a separate 'faculty' of memory. Three groups were chosen and all were given tests of the time required to learn poetry by rote, to learn prose by rote, to learn facts for sense, to learn a Turkish-English vocabulary, to learn historical dates, and then the memory span was tested. One group, the control group, had no special training between the first and second tests. The practice group spent 177 minutes learning poetry and nonsense syllable. The practice was from nineteen to twenty-eight minutes a day for eight days. The so-called training group spent the same time, but used 76 minutes in listening to rules for learning, and 101 minutes in practice on rote poetry and nonsense syllables. Then all were tested on the same kinds of material as were used before training. The training group improved most, the practice group next, and the control group least.

The training consisted in being told six of the rules we have discussed here: that one should learn by wholes; should attempt to recite as soon as possible after repetitions began; should use rhythm and group the material; should be mentally alert; should be confident; and should use secondary associations as is suggested by the memory schools. Knowing the rules, plus having an opportunity to practice them, had a marked effect on improving the capacity. The practice alone had less effect, yet a noticeable improvement could be detected in the control group from the practice necessary in the first test. That the improvement is due to hitting upon more efficient ways of learning is clear from the greater gain by those who were taught rules explicitly. That habits are the essential forces in improvement is evident from the fact that memory span and learning facts by meaning alone were much less improved than the other forms of learning. Winch and others have found that training in learning one kind of material may be an actual disadvantage in learning other kinds.

Obviously ability to learn improves with learning. The improvement is greatest for the same kind of material that is learned, but it does spread to other kinds of material, with greatest increase in capacity to learn similar material. The improvement is based upon the formation of habits. If the habits formed in learning one kind of material are not useful in a second kind, no improvement will result and there may even be a decrease in the rate of learning that form of material. It is not to be assumed that we have a special capacity or faculty which can be trained as one trains a muscle. Improvement in learning through practice is due to improvement in ways of attending, to forming good habits of repetition, and to increasing confidence in one's learning capacity.

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CHAPTER XVII

REASONING

In addition to the mere receptive and repetitive mental processes, man is also capable of manipulating impressions to form new combinations, which are quite as real as are the experiences he appreciates passively. This function we know as thinking or as reasoning. Included under thinking are a number of different minor functions, but all are concerned with problem solving. We may distinguish two of the more important of these functions which are characteristic, the one of practical, the other of theoretical problems. The first is the solving of practical problems which results in new constructions; the second is the process of understanding facts or laws that cannot be changed or that need no change. Developing the airplane or the radio illustrates the first. Appreciation of the relations of sun and earth to each other offers an instance of the second. The two processes are closely related. Usually one must understand before one can construct. A new invention may follow directly upon a new scientific discovery as the radio upon the discovery of Hertz waves, or it may develop gradually with the growth of many sorts of knowledge, as in the airplane.

The Background of Knowledge. — All forms of problem solving depend directly upon the background of knowledge and especially upon the definitely formulated knowledge of developed concepts and types. These were discussed in Chapter XIII. One can develop nothing new until one clearly understands the old, and understanding is largely merely a process of formulating separate experiences in concepts. A concept in turn is itself a method of ordering the experience with a class of objects in a way to eliminate inconsistencies. Concepts grow up spontaneously, but when they develop they are taken to be more real than the separate observations or experiences from which they are derived. To understand a new experience is merely to refer it to the appropriate concept developed from the organization of past experience. We shall see that the influence exerted by these organizations of older knowledge is important in the preliminary understanding and also in confirming or rejecting the suggested new constructions. Most reasoning is in general terms and the concepts make possible the generalizations of particular observations and conclusions.

The Natural History of Reasoning. — One can best understand thinking if one studies it in its practical setting. Reasoning is one of the most frequent of human operations, even if we think of it as the culmination of man's mental processes. Whenever a situation presents itself which old habits do not suffice to deal with, a man will cast about for a new solution. Similarly on the mental side when a fact is discovered which will not fit into the older ordered system of explanations, one feels impelled to discover a more satisfactory theory to explain both the old and the new. Reasoning as a whole must have a positive stimulus. The problem is always forced upon the individual by some inadequacy of old habits or of old thoughts, by something that goes wrong in the ordinary routine. Where habit and routine suffice, one never reasons. Necessity is the mother of all thought, as of all invention. Reasoning results when a man is thwarted in his mental or physical progress. On the mental side some fact presents itself that will not harmonize with the theories already developed. The number of species of beetles challenged Darwin to discover a reason; the flight of birds and insects challenged Langley and Wright to find some mechanical means of imitating them. Each suggestion that ideas may be translated into objects starts the discoverer on a quest for the means. Granted the problem, the next stage is an analysis of the problem into its elements or conditions to obtain a better understanding of what is to be done.

The Methods of Meeting Situations. — The analysis of the processes of thinking can best start with a simple instance by tracing the different responses that are made or may be made in its solution. Not all of the instances of reasoning show the complete form. Some are short circuited because the thinker does not need to make all explicit. It is interesting to show how the terms and functions, that have been developed by the logician in his centuries of analysis of thinking, can be fitted into the modern schema. The logician asserted that the first stage in thinking is judging. By judgment he designated the simple statement, the linking of one concept with another, as the 'tree is green.' The more modern logician and the psychologist believe that in a case of this sort we are always dealing with an analysis of a situation. The subject of a sentence or proposition is one concept which is applied to one phase of the situation; the predicate is a second concept that may explain the same object or situation. There is always something in the preceding phases of the reaction that determines what shall be noticed and how it shall be designated. Usually one is specially interested in the predicate. One would say the tree is green, only if one were seeking a green object to further some purpose, as in fighting a fire, when one desired a tool with which to beat out the flames that would not itself catch fire, or when one desires to hide a part of the camp. Corresponding to the need or purpose the desirable characteristic would be noted and remarked upon. The subject, the 'tree,' is largely incidental. It designates merely the place where the desired characteristic can be found, and is named as a result of a previous judgment.

Judgment in the Solution of a Problem. — When one is meeting a check in his progress towards a goal, the judgment is ordinarily the appreciation of the specific character of the hindrance. If the car one is driving suddenly stops, one begins to search for the cause. The first judgment may be the recognition of the stopping, although that is usually so obvious as to stimulate no remark. One then seeks the cause by looking to see if one after another of the familiar causes for stopping is responsible. The gasoline gauge is examined and if one distrusts it, the tank is opened and a rod inserted to test the quantity. The battery circuit is tested, the spark plugs examined. When a suspicion is justified by the examination, the problem is solved if the repair is one that has been made frequently. Buying or borrowing gasoline is a familiar operation. If the circuit is broken, the problem of closing it if the wires do not meet when stretched may be a difficult one. It is meeting these new situations adequately which provides the problem for the psychology of thought. This process comes most nearly under what the formal logician calls inference.

Wallas' Theory of Inference. — How a problem is solved has been much discussed by psychologists and by practical men. Graham Wallas has presented very well the limitations of our knowledge concerning that method . He divides into three the stages of solution after the problem has been isolated. The first is preparation. That includes the events of the life before the problem formulates itself, as well as in the period after that formulation. Anything that one learns about the problem will have some influence in determining the solution. No one has traced the exact relations between the knowledge and the solution. One must know the essential facts to solve the problem, but he may have all the facts and fail. Sometimes the men who know most are not the most effective.

The Period of Incubation. — After all knowledge that is appropriate has been acquired, there is a time of lying fallow, in which at odd moments and, if we may believe Wallas on the basis of reports from Helmholtz and Poincaré, the process of reaching a conclusion is furthered. Helmholtz reported his results came to him most often when he was away from his office on a vacation, and frequently when he was not fatigued as when he was climbing a gentle hill on a pleasant summer's day. Poincaré reported two instances of important discoveries when he was away from the routine. Once when he was doing his military service he hit upon the solution of a problem that had presented itself to him in the regular course, and another he solved when on a vacation trip. A questionnaire sent to the research chemists of the country reported that the solution of their problems came in a considerable proportion of the cases at odd moments when they were not dealing specifically with the problem that was solved. They called the conclusion a 'hunch.' One chemist said he had his 'hunches' most frequently when seated with his feet on the radiator looking out of the window and that it was at such moments he was worth most to his employer. The 'hunch' corresponds to what Wallas calls the process of *illumination*. Poincaré speaks of it as *clicking*.

The Illumination. — What is possibly most striking about attaining the conclusion is that there is no evidence that it is preparing until it comes. The thinker is not particularly aware that he is brooding over the problem during the process of incubation and rarely has any knowledge as to what in the immediately preceding experience leads to the development of the conclusion. Sometimes there is an indication in advance that a conclusion is to appear. This Wallas calls an *intimation*. It is a vague aura of the coming idea, a feeling that the thinker is getting *warm*, but it is only a slight premonition. So far as the thinker himself is concerned the conclusion comes for no assignable reason. No generally present antecedent process or condition can be given. There is the sudden lighting up of consciousness with the presentation of the solution of the problem. It comes as a bolt from the blue. Wallas adds a fourth stage after the conclusion is reached. This is *verification;* it corresponds to the processes of belief which we will discuss later.

Influence of Attitude on Inference. — Experimental studies of the process of inference under controlled or experimental conditions show one or two of the factors that are at work. If a man is given a small problem to solve and is watched as he makes each move, it will be seen that he makes a number of unsuccessful trials, in most cases, before he hits upon the right solution. If you ask him to think how he could solve the problem without actually making the movements, it is found that one idea after another comes before one is accepted as correct. Ideas follow about the same course as the actual movements. The man in both cases is much like the animal trying to get out of a box. The movements and ideas seem to be almost hit and miss. Both probably have definite causes in past habits and brain connections or organizations did we know them. Since we do not have sufficient knowledge of the action of the cortex, we may say that they represent chance trials.

Maier showed that much depended upon the attitude the thinker was in as to whether he succeeded or not. This determined the direction of his trials. Maier hung two strings from the ceiling with a distance between so great that a man could not reach from one to the other. The observer was asked to tie them together. A pair of pliers, and other tools were placed on a table with the suggestion that were any needed they were to be used. The tools were suggestive of other functions or acts than those that would solve the problem. Maier was struck by the fact that the workers were relatively little influenced by suggestions that might be given. Even when success followed a suggestion, the worker did not give it credit. The experimenter might set one of the strings swinging and awaken no response from the worker. On other occasions swinging the string might hasten the appearance of the solution, when the worker insisted he had not noticed the swinging. The solution desired was to tie the pliers to one string and start it oscillating so that it would swing within the reach of the worker as he held the other. When a thinker starts along one line of attack he requires a long time to change to another line. As long as he is in the attitude that impels to that line of attack, suggestions of any other mode of solution have little effect.

Change Direction of Approach. — In experiments with a class it was found that merely giving the rule of varying the method of approach was a help in reaching solutions. One half of an elementary class was given no instructions in how to solve a problem of this kind mentally. The other half was told that they should seek a new line of attack as soon as one was tested and failed. The actual tests showed that the group that had received the instructions was noticeably more successful and quicker in solving the problem. It is very striking that so short a period of instruction should be followed by such marked improvement. The failure of suggestions to act is an illustration of the importance of temporary attitude or purpose in the control of associations. When in one attitude one is blind to the importance of what does not harmonize with that attitude, however obvious it may be when in the appropriate attitude. The suggestion that one should look for new kinds of solutions served to help the thinker to develop a new attitude.

Ability to Solve Problems Is General. — Billings showed that the capacity to solve problems of one sort went with capacity to solve those in other fields. He prepared a list of problems in school subjects ranging from mathematics through physics to economics and sociology. Students were given the facts needed for the solution of the problems, and tested upon the facts to make sure that all were known. They were then asked to solve the problems. The results showed that individuals who solved the problems in one field quickly did about as well in the other fields. There was a coefficient of correlation of from 0.60 to 0.80 between success in different types of problems. There was a much lower correlation between success in recalling the materials of the tests and solving the problem. Little correlation was found between the number of courses taken in a subject and success in solving problems belonging to that field. Ability to solve problems also had little relation to standing in university courses or to intelligence as measured by mental tests. This lack of correlation with mental tests is probably due to the large place memory factors have in most tests used at present. The results of the experiments indicate that capacity for solving problems depends largely upon ability to see a problem in many different relations and that in turn upon ability to change quickly from one attitude to another, and so to approach the problem from many different directions. The ability to solve problems in one field is closely correlated with ability in all fields, however different they may be. It is also not closely dependent upon ability to learn or recall.

The Gestalt Interpretation of Problem Solving. — Wertheimer has suggested from the Gestalt point of view that problem solving consists in reorganizing the facts connected with the problem into a new Gestalt. The solution is attained when an organization of the materials of knowledge which bear upon the problem is reached that shall be consistent and relieve inner stresses. The realignment of the materials in a new Gestalt corresponds to the assignment of the problem to a concept or type in our earlier discussion. It is difficult to say from observation whether a suggestion which is successful in solving a problem is an organization or a type that has been developed in earlier experience. Both have the same function. Wertheimer also holds that the organization is completed at once and apparently from inner necessity. Observation of most thinkers indicates that there is always a series of tentative suggestions before the accepted organization or type required for the solution presents itself. We have referred to these suggestions as coming through trial and error. The Gestalt school prefers to think only of the final success and to think of that as due to some necessary law. It does not, however, assign any concrete explanation for its developing at the moment. The difference on this point is not great. An unexplained entrance is not very different from a chance entrance, for chance always means a statement of ignorance.

All of these discussions of the crucial phase of reasoning are at one in asserting that we are aware clearly only of the fact that the problem is solved and can give very few of the conditions that favor success. The problem must be clearly presented to a man who knows enough facts to develop suggestions. Given the problem and the interpretations placed upon it, the solution is attained by methods not directly open to observation. The correct suggestion is likely to come at an unexpected moment. Frequently it presents itself when the thinker is dealing with other tasks or is at leisure. Rules that have been suggested are largely negative. One is do not try too hard. Another is change the line of approach as often as possible. Too much thinking along one direction or under one attitude is fruitless. The greater the variety of ideas that present themselves to an individual, the more likely he is to solve any problem. Individuals who are capable of solving problems of one kind are also more likely to be able to solve problems of an entirely different kind. The rough outlines of the problem are the same whether we call the suggestion that presents itself, a concept, a *hunch*, an idea or a Gestalt. Our knowledge of whence or why it enters consciousness is equally indefinite, whatever we call it.

BELIEF AND PROOF

Since the process of inference is so largely concealed from us, and is so tentative in its character, it is important to study the way in which a selection is made from the suggestions that offer themselves. As was said all descriptions of inference emphasize the large number of suggestions that proffer themselves before one comes that will be accepted. It is evident then that the way in which a selection is made and the warrant that leads one finally to be accepted after so many have been rejected is an essential factor in effective reasoning. To know which concept or Gestalt is to be accepted is as important as to have concepts present themselves. Just as in memory, recognition selects from the suggestions, and the satisfaction or feeling can be thought of as deciding which movement shall be repeated and so be learned, there is in thinking a distinct warrant for the acceptance of the final suggestion. The process of accepting a suggestion is known as belief.

The Nature of Belief. — It is desirable that one should know all that is possible about the process of accepting and rejecting. Two slightly different phases of the problem must be faced. The first is of the nature of belief, the second of the methods of proof. Belief may be defined as awareness of the truth or falsity of a statement. Proof is the process of inducing the belief process in another or in one's self. Belief may be considered from two points of view. The first is the nature of the process itself. The second is the determination of the conditions under which belief arises. The mental characteristics of belief are apparently found first in the assured unfluctuating persistence of the assertion or conclusion. Secondly there is a slight feeling of pleasure, the usual accompaniment of the persistence of any mental process. Were they to stand alone neither persistence nor pleasure would be sufficiently unambiguous as characteristics of belief to insure discrimination of the belief process.

Doubt and Disbelief. — Belief may in fact best be defined in negative terms. We believe all that we do not disbelieve or doubt. Disbelief is usually due to belief in some other idea that suggests itself. When the first idea presents itself, it may not last long before another aspect of the problem appears. If that is accepted, the first is rejected and we say we disbelieve. When there is continuous alternation between looking at a statement or a conclusion in one way and then in another, we say that we doubt. In doubt unpleasantness predominates, and there are usually tense muscles and accompanying strain sensations. Thus, if one is considering a general problem, such as the advantages of controlled monopoly as opposed to unlimited competition, one will think of the importance of large production, of the encouragement to capital from certain returns, on the one side, and will believe in monopoly; when one thinks of the tendency of human nature to think first of its own advantages, and of the growing callousness of the dictator to those dependent upon him, permission to combine seems undesirable, and belief in monopoly is refused. The checks that come from state control will remove the doubt for a moment until the difficulties in exercising impartial control present themselves. Then the old doubt reasserts itself. Doubt is an expression of the conflict between beliefs, and the beliefs in turn depend upon the presence of various groups of experiences which make for the prominence of one attitude or another toward the assertion that is questioned.

In its less explicit forms belief seems to be an outcome of the harmony of a particular statement with the dominant group of experiences. This may be seen to advantage in the changes in belief as different possibilities are considered.

When one is caught off one's guard, when a proposition is viewed in the light of a limited group of experiences, one will believe things which would not be believed under ordinary circumstances. An exaggeration of the condition is seen in the dream, where we may assume that large areas of the cortex are inactive, and only the few active areas control consciousness. Then one will believe many constructions that are rejected as soon as one wakes. The dream during sleep need harmonize only with the partial consciousness, but as soon as one wakes it is necessary that it harmonize with all portions. This it fails to do, and it is then at once seen to be bizarre. In the play attitude, or in the artistic attitude as in novel reading, one may voluntarily hold part of consciousness out of action and pass upon the game or the work of art in the light of a partial experience. In this mood the result is accepted as true for the moment, although one is aware that it will not seem true as absolute fact. In general, belief is agreement between the construction of the moment and the total experience. The awareness of the agreement no more implies the presence in mind of all of the facts that are involved in passing upon the experience than recognition implies the presence of the associates that give the entering impression a place in the past, or the meaning of an image involves the full presence of all that is meant. Rather the thing believed merely holds the center of the stage without wavering or opposition, and that, with possibly some slight feeling, constitutes belief.

Proof a Justification of Belief. — While belief is sufficient justification for a conclusion on the part of the person who believes, the conclusion may not appeal so strongly to the listener or to others. It is this fact which makes proof necessary. Since justifying the conclusion is the one part of the reasoning process that is self-conscious, it is the process to which the formal logician has devoted most attention and which he is inclined to consider the only part of the reasoning process. Two forms of proof are to be distinguished, the *deductive* and the *inductive*. The typical deductive proof is through the syllogism, and this consists, in essentials, of referring the particular conclusion to some generally accepted principle, to a general law that is typical of all others. Just as the judgment consists in referring some particular object or difficulty to a typical difficulty or concept, the proof consists in finding a universal statement under which the particular conclusion that has been obtained may be brought and thereby made to seem true. The mere mention of a suitable general law arouses the peculiar cortical irradiations of associations that excite belief. First it should be said that nothing is proved that is not questioned. For one's self, belief suffices, and for most of the statements of everyday life as they are made to others no proof is necessary. Proof is given only when one hears or fears objection from one's listeners, or when one desires in an explicit form to test for one's self the truth of the conclusion.

Deductive Proof. — The oldest and most frequently used form of proof is the deductive. In essentials this consists in referring the new or questioned solution or invention to an old or familiar class. In simple cases the familiar class is merely mentioned. In more complicated instances the given problem is analyzed into a number of simpler elements and it is shown, as in a problem in physics, that the solution in question makes use of a number of the simpler and more familiar steps. The formal logician has reduced proof to a schematic form in the syllogism. The syllogism is a group of three statements, of which the first contains a familiar general statement which is used to justify the conclusion. The statement to be proved is put last and the two are united by a statement which indicates the relation. The general statement is known as the *major premise*, the connecting statement is the *minor premise*, and the statement to be proved is the *conclusion*. Thus, to choose a favorite instance, one might desire to prove that Socrates would die some day by asserting the unquestioned general principle that all men are mortal. This takes the form

All men are mortal,	(*Major Premise*)
Socrates is a man,	(*Minor Premise*)
Therefore Socrates is mortal.	(*Conclusion*)

The reader can give this argument a setting if he imagines the members of the Areopagus arguing over the feasibility or desirability of inflicting the death penalty upon Socrates. This syllogism might be used either to meet the statement that it was not possible to inflict the death penalty, because of the prominence of Socrates; or it might be made by one who objected to the death penalty on the ground that Socrates would die anyway in the natural course of events and so would not be a permanent danger to the state. It is obvious that the incentive to the syllogism must come from some one who has asserted the conclusion, and has had it challenged. The syllogism is a form of proof, not as is generally assumed a method of reaching conclusions.

The syllogism is effective for proof just because it connects the new with an already accepted fact or group of facts. When the reference has been made, the belief that attaches to the old and familiar is transferred to the new. The effect seems to be one of arousing masses of old experience which by their very arousal serve to stimulate the belief attitude. The statement can add nothing to the new and must already be known, or it would not be accepted by the man who is convinced. The utterance of the general principle seems to arouse the memories of the older cases and to crystallize them. Belief follows. The essence of the syllogism consists in this reference of the doubted to a familiar group. It may be given less formal expression and be equally effective. James, for example, shows that if one were asked why one placed a bit of match under one side of the chimney of a smoking lamp, the device could be justified by saying that it would admit air. The value of this might be questioned also. In that case it would in turn be justified by reference to the fact that burning is a form of oxidation and will not be complete when the supply of air is deficient. If that were questioned, one would be compelled to refer to chemical formulæ. In fact complete proof on any point might require reference through a large number of steps. Each of these might be put in the form of the syllogism. Fortunately, a reference to one more general principle in any brief way usually is sufficient to arouse belief.

Inductive Proof. — The other form of proof, the inductive, consists in counting instances in determining how often the conclusion is true. If in the past a suggestion has worked on every occasion, we are prepared to accept it as true. The effectiveness of this proof lies in the actual study of past cases or in experimental repetition and verification of the conclusion. From a study of vital statistics one knows inductively that all men die. One knows that an aëroplane will fly, because it has flown. The whole proof is dependent on assuming that what has happened will happen. In one sense the two proofs tend to come together, since of the empirical proofs only those are accepted which are in every way similar, which can be referred to the same general principle. On the other hand, the general principles that constitute the major premises of syllogisms and the accepted truths are probably in the last analysis derived from experience, but experiences coördinated and tested by particular applications and by their harmony with other general principles.

A general principle is frequently suggested as the result of a few observations, is tested by other observations, then is compared with other general principles that have also been suggested and tested by other single observations, and, if all harmonize, it gradually comes to be generally accepted. In most subjects controversies over general principles are current at all times, because each is in harmony with certain experiences and out of harmony with others. Settlement comes with more accurate analysis of the problem, with more careful study of the facts, and, where experiment is possible, by making crucial tests of each. But in no case is it possible to say that organized previous experience has not had some share in the proof, nor is it possible to assert that observation of particular experiences, induction, shall not have contributed something. When reference to generalized earlier experience is more in evidence, the proof is called deductive; when particular cases, statistics, or experiments are more prominent, the proof is regarded as inductive; but neither can be completely divorced from the other.

It is important to note that each of the actual steps in reason implies a reference to the system of knowledge. This in turn may be regarded as a result of the organized past experience of the individual. The first stage in each of the steps is a vague awareness. This is made explicit by seeing it as an instance of the general notion. A difficulty with a theory is appreciated first as a mere dissatifaction, a feeling that it is not quite in harmony with the facts. This is made definite when the defect is seen as an instance of a specific concept or principle. Similarly when the suggestions for the solution of the concept present themselves, they are passed upon as satisfactory or unsatisfactory immediately by the belief or disbelief process. This must be verified by reference to established principles or concepts before the proposition is finally accepted as established. This is the process of proof. Thus at each step we first have a vague feeling that all is right or that something is wrong. Complete understanding of the difficulty always implies a reference to organized knowledge, as formulated in concepts and general principles or laws.

SUMMARY

Illustration of Reasoning. — We have asserted that reasoning may be conveniently divided into four stages. First is the presentation of a problem by the thwarting of the progress of action or the appearance of an inconsistency in a theory. Second is the active process of understanding this difficulty by referring it to a concept. This is called the judgment. Third is the truly original aspect of thinking, the discovery of a new device, or a new way of organizing knowledge to eliminate the difficulty. Fourth and last is the process of verification or proof. We can make clearer the actual application of this classification to practice by a study of the way in which Darwin and Wallace developed their doctrine of natural selection. It happens that in this case two men, travelling independently practically the same course, arrived at the same conclusion, and we have the process recorded by one of them and confirmed by mutual friends. Dr. Wallace,[1] in modestly disclaiming any priority to Darwin in the discovery, traces in a paper before the Linnæan Society the facts that led both to hit upon the idea and to its statement. First with reference to the formulation of the problem:

"First (and foremost as I believe) both Darwin and myself became ardent beetle-hunters. Now there is certainly no group of organisms that so impresses the collector by the almost infinite number of its specific forms, the endless modifications of structure, shape, color, and surface-markings that distinguish them from each other, and their innumerable adaptations to diverse environments. . . . Again, both Darwin and myself had, what he terms 'the mere passion of collecting.' . . . I should describe it rather as an intense interest in the mere variety of living things — the variety that catches the eye of the observer even among those which are very much alike but which are soon found to differ in several distinct characters. Now it is this superficial and almost childlike interest in the outward form of living things which, though often despised as unscientific, happened to be *the only one* which would lead us towards a solution of the problem of species. . . . It is the constant search for and detection of these often unexpected differences between very similar creatures, that give such an intellectual charm and fascination to the mere collection of these insects; and when, as in the case of Darwin and myself, the collectors were of a speculative turn of mind, they were constantly led to think upon the 'why' and the 'how' of all this wonderful variety in nature — this overwhelming, and, at first sight, purposeless wealth of specific forms among the very humblest forms of life. . . . Then, a little later . . . we became travellers, collectors, and observers in some of the richest and most interesting portions of the earth; and we thus had forced upon our attention all the strange phenomena of local and geographical distribution, with the numerous problems to which they give rise. Thenceforward our interest in the great mystery of how species came into existence was intensified, and — again to use Darwin's expression — 'haunted' us.

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[1] A. R. Wallace, "The Origin of the Theory of Natural Selection," *Pop. Sci. Monthly*, vol. lxxiv, pp. 398 ff.

"Finally, both Darwin and myself, at the critical period when our minds were freshly stored with a considerable body of personal observation and reflection bearing upon the problem to be solved, had our attention directed to the system of *positive checks* as expounded by Malthus in his 'Principles of Population.' The effect of this was analogous to that of friction upon a specially prepared match, producing that flash of insight which led us immediately to the simple but universal law of the 'survival of the fittest,' as the long-sought effective cause of the continuous modification and adaptation of living things."

This shows that the problem had been set for both by almost the same conditions and that the solution had been attained in the same way, but the method of proof devoted to the suggestion was altogether different. Darwin spent thirty years in collecting and in writing out the evidence with only one mention of his theory to Sir Charles Lyell. Wallace, on the contrary, sat down at once, wrote a sketch of his theory, and, curiously enough, sent it to Darwin with the request that it be published. On the advice of friends Darwin presented the paper with a sketch of his own theory to a meeting of the Linnæan Society July 1, 1858. Darwin said that even the words of Wallace's paper were so nearly like his own that one might have supposed that he must have seen it before he wrote. Wallace emphasizes the influence of similar circumstances upon the common result:

"This view of the combination of certain mental faculties and external conditions that led Darwin and myself to an identical conception also serves to explain why none of our precursors or contemporaries hit upon what is really so very simple a solution of the great problem. . . . And now to recur to my own position, I may be allowed to make a final remark. I have long since come to see that no one deserves either praise or blame for the ideas that come to him. . . . Ideas and beliefs are certainly not voluntary acts. They come to us — we scarcely know *how* or *whence*, and once they have got possession of us we cannot reject or change them at will. It is for the common good that the promulgation of ideas should be free — uninfluenced by either praise or blame, reward or punishment."

In this sketch Wallace marks out explicitly three of our stages — the arousal of the problem, the hitting upon the solution, and the proof. The second, the analysis of the problem or judgment, can be seen implicitly in the many forms that the problem took as the how and why of species became prominent at different times. Observation will show that any clearly formulated bit of reasoning takes essentially the same course. Most of the thinking of our daily life, even in important decisions, stops with the implicit belief. The formal justification of the conclusion is not made. However, as we have seen, the unformulated but organized earlier experience is at work in accepting or rejecting these conclusions through the immediate belief processes, just as it is in the more formal operations. The warrant is the same, although the form in which it is expressed is different.

In reasoning, then, we see an advance made upon the accumulated knowledge, but an advance that is always made possible and controlled by that accumulated knowledge. One understands the new presentations and the new difficulties in terms of the organized old experiences, the types and concepts; one obtains suggestions for new solutions on the basis of analogies with the old; and, when obtained, the suggestions for new solutions are justified and tested in advance of actual use in the light of the organized knowledge. While new experiences and new trials are constantly increasing the sum total of knowledge, it is only by virtue of the previous accumulations and organizations that the new can be understood and that one may venture to test the new suggestions in action with even fair assurance of success.

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CHAPTER XVIII

IMAGINATION AND DREAMS

A LARGE part of our life sleeping and waking is spent in mental processes, intermediate between remembering and reasoning, which pass under such terms as imagination, revery, and day-dreams. Even during sleep we have the conscious processes that we know as dreams. These various processes are alike in that they are due to slightly controlled connections, continue without definite purpose, and give pleasure because of the nature of the constructions. The laws of origin of the imaginative processes are approximately the same as those for memory and reasoning, but the ends and controlling processes are very different. Reveries are evoked in accordance with law, as are memories and the products of reasoning; but the constructions are new, and consequently cannot be recognized, as the products of memory can. At the same time imagination differs from reasoning in that reveries have, at most, a very limited truth; they are not believed, or are believed to be true only under very special conditions. If we seek the criterion of the group we find it in a lack of definiteness rather than in any positive characteristics. It is marked by the free action of the mental machinery.

Imagination and Life. — It is into this type of mental life that we fall the moment we are free from a serious task. It must be confessed that day-dreaming occupies many of the intervals in serious tasks, in many cases time that should be given to the duties of life. When the clerk at his desk has a moment he finds himself constructing for himself a world that is more pleasant than that in which he lives. The student, during the uninteresting periods of a lecture, finds his mind wandering off to a world of future conquests, or to imagined changes in his lot. The plowboy fills his time picturing a state in which he will sit in the house and direct the labor of others, and no longer hold the handles of the plow. The spare time of all alike, high or low in station, intelligent as well as unintelligent, is spent in spinning fancies. Thinking towards a definite goal is a matter of effort, of distinctly greater effort than the purposeless wandering of the mental images.

The types of these imaginings range from passing day-dreams, unrecorded and transient, to the work of the novelist or the poet, and the creations of the painter, sculptor, and musician, on the one hand, and on the other, to the great constructive works of the inventor, as the imaginative process merges with reason. If we were to give a complete explanation of these simpler states of mind we would at once have a theory of art in all of its forms, and of certain of the achievements of the inventor.

PLAY

Imagination and Play. — One can find an analogy for operations of imagination in the purposeless activities of animals and children, which we call play. Here on the active side we have the same series of tendencies, probably the same control or lack of control that we find in the mental state which we have been describing. The cause of play is, in part, the mere inability to keep still, the activity of the neuromuscular mechanism, that must respond to every stimulus with movement. This overflow of activity, the inability to remain quiet, explains the constant movement of the child; it does not explain the particular form that the movements shall take. Many of the movements are determined as much by the operations of the laws of imagination as is the mental process itself.

Play as Expression of Native Tendencies. — Some plays may be regarded as deriving their appeal from inherited tendencies. Play in this case, as the mental activity in imagination, is not for a serious purpose. The responses may appeal because of the inherited pleasure, but they are not essential to existence in the situations that evoke them. The fighting plays of boys and the playing with dolls and at housekeeping of girls are both sets of activities which will be called into use later. In these games what is innate is not so much the motor response as it is the pleasure that comes in thinking and acting out the situation. There is a pleasure in fondling and dressing the doll; but it is a question whether the doll would evoke the instinct unless it were thought of as a child. Not the immediate response but the imaginative transformation of the doll into a child, and the change of the situation as a whole into the home situation, constitute the essentials of the play experience. This setting changes, and the reaction with it. The doll may be thrown down or hidden in a basket when the game is over, as a real child would not be. It is a child only while the game is on. This make-believe, with the changes in the character of the assumptions with changing attitude, is what is at the bottom of the play motif. It makes it possible for the child to act out situations which are pleasant to him, which he is not able to attain in reality.

The games give expression to different inherent tendencies. Each of the groups of so-called instincts discussed in Chapter VII may be recognized in the common games. In addition to the household games which are indulged in mainly by girls and which are pleasant because of the appeal to racial instincts, we have games of contest, which may permit expression of the primitive fighting instincts, or the plays of skill, which are the outcome of rivalry in its varied forms, coupled with the pleasure in acquirement of skill for skill's sake. Any game or instrument which increases capacity, which gives a chance for a struggle with possible assurance of superiority over some one else, is pleasant. The overcoming of danger, the accumulation of real or imaginary valuables, as in games of chance, are pleasant because of the appeal to the individual instincts. The games that involve rivalry and the use of instruments that increase the power of the individual give a satisfaction because of appeal to the sense of individual importance, and may therefore be classed under the games that appeal to the social instincts. In practically every case the pleasure of the game is instinctive, but it is always itself a product of the imagination which constructs a situation representing some other real situation that would evoke the instincts in question.

REVERY

Day-Dreams Involve Instinctive Elements. — The same general statements may be made of revery or day-dreaming. In the revery, one spends time in permitting the construction of situations in idea that would be pleasing were they present in reality. Some of these constructions are real plans for the future. Many, however, are nothing more than play ideas, in which one thinks merely how pleasant it would be if the imagined constructions should come true. One is pleased by the mere passing of the ideas and has no thought of attempting to make the desired or imagined situation real. Constructions are pleasing because they put the individual into situations where he could satisfy his tendencies. He thinks of himself as rich beyond any degree that his prospects warrant; he thinks of himself as writing books that would give him renown; he pictures himself as doing deeds of valor on the battlefield; or of rescuing beautiful ladies who shall reward him with their love. Self-aggrandizement, success, social appreciation, are all his, in his reveries. They satisfy the same instincts and impulses as do his games, aside from the desire for actual physical exercise and the relief of tension that is derived from motor activity. Like play, it is a process of make-believe; but the make-believe is limited to ideas, it does not extend to action.

Control of Revery. — We may assume that the course of the ideas is determined by the laws of association. Each idea that appears or each object that is seen starts a series of ideas, by the mere spread of the impulse to the other cortical areas that have been connected with it. As a rule, mass dissolves into mass in the process ordinarily called association by similarity. Pictures of considerable complexity succeed each other as wholes. The explanation for the succession is the connection formed between groups of neurones, just as it is in all recall. There is some degree of control of the recall through the attitude and wider mental settings. The succeeding ideas are in large measure congruous; they all tend to the development of a consistent whole, although the purpose may be little in evidence when the construction starts its course. The idea that shall follow a given idea is determined by the wider setting, the objects round about, and the ideas that have gone before. It is an instance of controlled association, although, as is usual, the control is not in evidence.

The factors most evidently lacking in imaginings of this type are the selection processes which pass upon the results in both reasoning and memory. In memory, the products of association are recognized, and if they are not recognized as having been present before, they are rejected, and new recall is encouraged by supplying new stimuli to the association processes. One thinks back to the point where one left the main track of recall, and waits for something else to be suggested, or one looks about for some object that will suggest the idea desired. In reasoning, as we have seen, there is also a definite purpose, and one waits for the construction to appear which can be believed to fulfill or satisfy the purpose; the suggestions are sometimes as little controlled as in imagination, but there is always selection from the numerous ideas that present themselves of those that fit the conditions.

Selection in Revery. — In the revery the ideas are seldom controlled in their course, and there is little selection. The only choice exerted is in not permitting one's self to dwell on the uninteresting. When uninteresting ideas appear for too long a time, one will either start a new train of thought or go to work. The interesting, however, is not necessarily pleasant. As will be seen, we occasionally enjoy picturing ourselves in adversity, and as overcome by the thrusts of an unkind fate. One usually pictures one's self as overcoming the obstacles and rising to new heights, but one seems at times even to enjoy representations of one's own misfortune. Reveries, from the standpoint of association, are mere trains of thought that run their course with a minimum of control in accordance with the simpler laws of association, subject only to the vetoing of the boresome.

THE UNCONSCIOUS

Freud's Theory of the Unconscious. — In connection with this and all of the other forms of imagination, from dreams to humor, we should mention the theory of Freud which has been attracting the attention, particularly of the physician, for the past three decades. For Freud, the explanation of any mental operation that is strongly emotionally toned is to be found, not in the cortical connections, but in the work of what he calls the subconscious or unconscious. According to Freud, one must recognize two levels of consciousness or mind: one we have been studying so far; the other lies hidden below that, and is not open to observation by the individual. Its action can be inferred, merely, from the nature of the mental processes and the behavior of the individual. The desires of the subconscious are the primitive ones determined by instincts. They are opposed by what he calls the censor, which corresponds pretty closely to what we have been calling social pressure, the influence of social conventions and ideals which will not permit the ideas of lines of conduct suggested and determined by these instincts to rise into consciousness. Freud goes so far as to picture the unconscious as a person, like the conscious self as a whole, which has definite desires, and also can seek different means of accomplishing the desires, some of which are very much like reason. We are to think of mental life as a struggle between two persons, one impelled altogether by instincts in the desire to gratify the individual — and in Freud's theory particularly the racial instincts; while the other lives a life of convention, in accordance with the rules of good form. The latter is the conscious life, which knows its own ends; the former is always concealed, and while its aims are known to itself, presumably, they never appear above the threshold. The upper, conventional mind is the mind we know, or are presumed to know; while the hidden motives come mostly from the subconscious.

DREAMS

Freud's Theory of Dreams. — The application of this theory is seen most completely in the explanation of dreams. Dreams, for Freud, are always attempts of the unconscious to force its desires upon the upper consciousness. Possibly it would be more in accordance with the spirit if not the letter of Freud to say that they are a means by which the man as a whole enjoys the thoughts, desires, and memories which are usually the perquisite of the subconscious alone. It seems at least that were the enjoyment limited to the subconsciousness, it might receive quite as much satisfaction in dwelling on the desires, or revelling in forbidden memories alone, and would have no reason to share them with the upper, apparently unwilling, puritanical over-lord. Whatever the incentive, the Freudians assure us that dreams are vehicles of the thoughts and desires of the unconscious.

But even in sleep the censor is not altogether off guard, and in consequence it is necessary to outwit it by various stratagems. All dreams are asserted to be suppressed wishes. When the wishes are distasteful, the dream actually expresses the opposite of one's real desire, or the dream is clothed in symbols, which seem innocent, but which the unconscious understands to be really sexual in meaning. It is asserted that the joy which the upper consciousness, which does not understand the symbolism, obtains is a vague reflection of the delight of the unconscious. It should be added that Freud insists that the dream usually starts from or is suggested by an event of the preceding day, which serves to recall some experience of childhood which made a strong impression because of its emotional content. For Freud, these experiences are always sexual in character, and hence always hide behind symbols. It should be said that many Freudians widen the meaning of the sexual to include other closely related instinctive activities and feelings, an extension which obviates certain of the difficulties we have emphasized.

Interpretation of Dreams. — The difficulty in interpreting the dream lies in the fact that it may either be a wish directly expressed, or the reverse of the real wish, or it may mean something altogether different, that can be determined by reference to the symbolic relations known by experience to the physician. If, for example, one dream that a friend is dead, it may mean either that one really wishes he were dead, or by opposites, that he should enjoy renewed and abundant health. Since for Freud many common objects have a symbolic meaning, and all mean something sexual, it is always easy to interpret the dream as meaning what the interpreter wishes it to mean. A serpent, a flower, a landscape, a room, falling, are for Freud all sex symbols. Obviously it is somewhat disquieting to tell dreams to a convinced Freudian, as some of the accepted means of interpretation would be sure to make possible a sexual interpretation.

Dreams Explained by Association. — The alternative interpretation of dreams is that they are mere association processes, which run their course without the usual controls. Ordinarily the dream starts, as Freud says, with some stimulation left over from the day before. This suggests ideas from the more or less remote past, as Freud asserts, but we may assume that the ideas that come are aroused by the ordinary laws of association.

Dreams may be initiated by external stimuli. Cold water applied to the face may produce a dream of being out in a snow storm, or more complicated constructions. Professor Shepard reports that in an experimental investigation of the circulation in the brain during sleep, the patient showed marked changes in the volume of the brain as men passing spoke outside the window. The patient was awakened by the experimenter, and reported a lengthy dream of an experience at a party. Numerous similar instances are on record. Freud insists that the external stimulus in these cases arouses the repressed experiences only, and that the main content of the dream is supplied from the subconscious. On the other explanation, the sensations would arouse associations that would follow their normal course, but a course that was not checked or controlled by knowledge as in the ordinary waking state.

Condensation in Dreams. — All psychologists agree that dreams are much condensed. They are merely hinted at or represented by the content of the dream. When recalled they are much elaborated. Freud would make the condensation even greater than the other workers, for he believes that the dreamer is not aware of many of the meanings which are implied, but that these must be supplied, if at all, by the physician who interprets the dream by symbolism. Each object has some hidden meaning which can be elaborated only by one who knows all the significance of the symbols. In addition, the important parts of the dream are likely to be displaced, so that they are made to occupy a much less prominent place than they should have, in the interest of throwing the consciousness off the scent. Both condensation and displacement are according to Freud means of concealing the real meaning. The truth is not recognized by the dreamer even in his most complete interpretation or reproduction of the dream. Havelock Ellis and most other writers who are not Freudians, on the other hand, believe the condensation to be a short-hand representation, for which the dreamer holds the key, and which he elaborates in his recall without knowing that the dream was in short-hand.

Other Experiences of the Unconscious and a Critique of Freud's Theory

Freud's Theory of Revery. — If one transfer the Freudian explanation of dreams to the day-dream and ordinary revery, it would hold here, too, that the imaginary construction was the expression of the subconscious, and that the materials of the day-dream, particularly of those parts that give the most pleasure, are to be interpreted by symbols as meaning what they do not seem to mean. It is probably true that some of our day-dreams are the expression of wishes; hardly likely, however, that these wishes are often concealed under the form of contraries. Freud would have certain of them run as symbols, still more take the form of expression of a desire under its opposite, so that one would build elaborate constructions in which one came off second best, or would think of misfortunes befalling members of one's family, when one was really enjoying thoughts of triumph. One may say at least that the dream and the day-dreams have the same explanation, even if one does not decide whether the Freudian or the general association theory is the more satisfactory. Varendonck in his *Psychology of Day-Dreams* has made an elaborate application of Freud's theory to revery. He holds that the unconscious, the foreconscious, and the conscious all combine and that approximately the same laws are to be recognized in each.

A Critique of Freud's Theory. — The objection to the Freudian theory as a whole lies first in his general conception of the unconscious. One cannot know what there is in the unconscious, because by hypothesis it is altogether removed from observation. It is, furthermore, undesirable to give explanations in terms of assumptions that cannot be verified. Again, the Freudian explanation is so general that it applies to everything and therefore to nothing. It is just as much a question why the unconscious should desire to dwell on sex matters, or why it should desire to forget certain events, as why the conscious should have the same attitude or desire. There is no chance for a specific explanation of any of these mental events when once they are put in the unconscious. Were there any certainty that the unconscious existed, these lacks would not prove fatal. But as long as we have no absolute evidence of its existence, and there is no particular advantage in assuming it, the assumption seems uncalled for. A more serious logical difficulty with the Freudian explanation arises from the very ingenuity of the theory of symbols. The symbols include practically all of the objects that commonly appear in dreams, and they all symbolize the same experiences. If all dreams signify the same thing, and that thing is bound sooner or later to enter into the experience of any individual, it seems to follow that the assumption is proved. When one attempts to show from this that the ideas are really symbols, the proof is absolutely inconclusive. It amounts to nothing more than reasserting the assumption, and then stating that every one dreams in symbols. Brilliant as is the hypothesis, one cannot regard it as established or capable of being established. It has proved of practical value in suggesting means of treating patients, but it cannot be highly esteemed as an explanation of mental operations.

Freud's Theory of Forgetting. — The Freudian theory has been extended to explain many other phenomena in the individual and the race. Freud asserts that the disinclination of the unconscious to face certain facts explains many cases of forgetting. When a man forgets an errand, it is because the errand is really distasteful to the dominating subconscious. One forgets the present intended for the individual whom one does not like, but to whom one feels under obligation. The names of individuals one does not like are forgotten, even when they have been frequently repeated and should be thoroughly learned. Similarly Freud would explain accidents in which objects are dropped and broken as due to a real desire to break the objects. He instances a case in which he had broken a vase in handling. On thinking back he found that the vase was a present from a person whom he disliked, and he believed that the unconscious broke the vase to remove a reminder of the disliked individual. This he regards as typical of accidents, just as forgetting the disagreeable through the intention of the unconscious is typical of forgetting in general.

Freud's Theory of Wit. — Not all of the activities of the unconscious are undesirable. Witty remarks Freud would ascribe altogether to the unconscious. Wit always has a bitter element in it. This he asserts is not intended, nor is the probable effect seen by the speaker. The unconscious, with its usual malevolence, wounds the victim when the upper consciousness might be well disposed to him, or at least unwilling to offend the conventions which prescribe considerate treatment for all with whom one comes in contact.

Symbolism in Myths. — The symbols of the unconscious have been extended to explain all of the myths of the race.

Here the explanation offered by Freud is that the folk mind would dwell by preference upon sex matters, but conventions which develop (their development is not described) prevent the formulation of these stories of deepest interest in direct form. In consequence the early bards and men of olden times who formulated the folk tales took advantage of the device of expressing the ideas in symbolic form, and the psychoanalyst alone has been able to interpret the real truths which they contain. It is interesting to ask how and why the symbols took the exact form that they are assumed to have taken. Jung has suggested that they in some way became part of the inheritance of the race and have been handed down through the unconscious in the same way that the instincts are transmitted through the physiological organism.

The whole belief in symbols is one of the least satisfactory phases of the Freudian hypothesis. There is no way of verifying the hypothesis, because the unconscious can give no direct report. The only excuse for the assumption is that in the treatment of hysteria a patient will now and again report a dream or a day-dream, and when the physician has assumed from the theory of symbolism that there must have been some repressed or forgotten sexual experience, he has been able to confirm its existence by psychoanalysis. This confirmation is less satisfactory than it would be if any of the symbols meant anything other than sex in some of its forms, or if the physician who believed in Freud would under any circumstance be satisfied with anything other than sex memories as a cause of the disease. It is also difficult to see what pleasure could have been found in myths whose symbolism had remained undiscovered until thirty centuries after the original formulation.

ART

Art as Play. — In one of its aspects all art is to be regarded as a form of play. The novel and the drama are day-dreams of the author which by their character are instinctively pleasing to the reading or theater-going public as a whole. The stories that please are, as a rule, stories which represent the hero in activities that it would please us to share. We can sympathize with his victories, and with his defeats which are nearly always temporary and which give zest to the final triumph. From the more intellectual side they may be considered as studies of the laws of human conduct, as a result of making certain assumptions and determining what the natural outcome must be. In this sense a novel or a drama is a depiction of the laws of human action, which permits the author to show what a man must do under a series of circumstances, where these circumstances can be worked out free from the many unknown forces which are constantly interfering with the action of the known conditions in real life. This intellectual interest may lead one to find pleasure in the unpleasant ending, thus making tragedy vie with melodrama in appeal.

Sculpture and painting gain part of their appeal from the fact that they put day-dreams in form, and represent the pure conditions of form in a way that frees them from the accessory chances of real life. In part they have an appeal from the representation of the forms that have a native or instinctive beauty. This beauty may come from association with other events or objects that are themselves pleasing, as the proportions of the human body seem to be repeated in many of the structures that please but which do not even suggest the human form. It may be that certain forms have a native attraction, with no need for association to intensify the pleasure that comes from them. Our purpose here is merely to indicate that art has in it certain of the elements of play, in so far as it is a representation of one phase of life under the assumption that it is the whole. This make-believe unites all forms of art with play, as with the day-dream.

We may mention the explanation of the Freudians that art, too, is a form of symbolism in which comparatively innocent terms, forms, and ideas represent the sex factors. The primitive symbols are applied to novels, to paintings, to sculpture, in exactly the same way as to myths. Possible illustrations readily suggest themselves. For the sake of completeness we may assert that the Freudians find the symbols of the dream life embodied in many of the forms of art as in the myth. The method of proof is the same as that for the other applications, in the similarity or fancied similarity between objects depicted in art and the symbols of the dream and myth.

General Remarks on Imagination

We see, then, that the dream, the day-dream, or revery, play, and all the creative arts — in particular, the novel and drama, painting and sculpture — have many characteristics in common. All find their justification primarily in the fact that they please, all are largely random activities, controlled only so far as they lead to a pleasant end, but an end that is not foreseen in advance. All alike, again, are processes that are indifferent to truth. They are supposed to reach conclusions that are at most but partially true; although in art, by pressing home what is true under certain assumed conditions, they may enforce truths that could not be presented in the more complicated realities of life. The results are pleasing because they harmonize with the instincts; and because on the intellectual side they often present the solution of real problems in a way that would not be possible theoretically.

One explanation of the causes that lead them all to take the course they do has been found in the laws of association, the mere connection of neurone with neurone, on the nervous side, controlled by the wider interaction of large masses of the cortex in checking the elements which do not harmonize with the whole and in furthering the activity of those parts that do harmonize. As in all association processes, we do not know what is coming before it comes. At the most, the individual knows what the general end of all the thinking may be or what he would like it to be. If he knew more it would not be necessary to think.

As an alternative explanation of the course of these play types of thought, we have the assumption of Freud that they are results of definite intentions on the part of the unconscious. This unconscious we none of us know directly; and did we know it, we would have once more the problem, that we have with the conscious, as to why its thought processes act as they do. Were it possible to know as much of consciousness as we are assumed to know of the unconscious we would have no occasion for the hypothesis that the latter exists. If we were to assume the latter, we would need the same study of the laws of succession of its ideas as that which we have given of the association processes, if the explanation is to have any value. For this explanation, a study of the laws of connection and of their controls is essential. It is better to unify them and explain them all in terms of a single self, than to assume a second self which would in its turn require the corresponding explanations. There is no sufficient reason for belief in an unconscious.

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CHAPTER XIX

THE CONTROL OF MOVEMENT — VOLITION

EACH of the more complicated intellectual processes affects in some way the active life of the man. We must consider movement not merely as the result of inherited connections and of the simpler forms of learning, but must take into account the influence of the higher conscious processes in the control of action. We have traced in the earlier chapters the means by which movement processes are changed from the originally inchoate tendency of the organism to respond as a whole, to the development of a capacity for isolated movements. These are adapted to the accomplishment of a single end on stimulation by a definite group of excitations. If we regard our earlier discussion in Chapter X as showing how the motor parts of the body are brought under direction, we still must consider how the movements are used for our more conscious purposes.

The Drives in Human Action. — The voluntary acts of an adult man are determined in their course and have as their incentives drives of the same general character as those which impel the movements of the lower animals. The stimuli to action are provided by the external sensory excitations of the moment, acting upon the individual in coöperation with widespread internal stimulations. Hunger and thirst may be effective, although in civilized man they seldom have a chance to become very strong. The endocrine glands are constantly active in increasing the tone of the sensori-motor mechanism. All of the mechanisms controlled by the autonomic system which are active in emotion also supply sensations which influence the wider volitional responses. The decisions of the man who is nursing a grudge or who is wildly in love are different both in their character and in the vigor with which they are carried out from those of the man who acts in the cold light of reason. The effect of any stimulus from without will be very different according as it find the man with or without these various internal stimulations.

Ideals in Control of Acts. — The normal adult human has his activities determined in addition by the effects of various memories of past activities and their outcome. The memories of past activities become consolidated into fixed notions of what the results of any stimulus are to be and these combine to determine the response. An idea or sensation becomes the symbol of a desirable condition and, when the sensation presents itself, the old outcome and the emotions aroused by it set up a motor response which turns the individual toward or away from a course of action. These ideals develop strength from the social forces and controls. A purpose develops in harmony with the aims of the social group to which the man belongs and the pressure from the group drives the individual to the attainment of the ends accepted by the group. For the adult the drives are found not alone in the immediate internal and external stimuli, but in the complexes of memories, with their accompanying emotions derived from previous experiences of all sorts. A purpose or an ideal is a precipitate from numerous memories of earlier acts with the emotions that they arouse. We must take these for granted as the background against which the real drives, the stimuli from the present environment, are effective.

The Initiation of a Movement. — One problem which is of the utmost practical as well as theoretical importance is how we start a movement after we have learned it. This problem is the more difficult to solve since we are not definitely aware of all of the steps in the execution of a movement. We do not have in consciousness a knowledge of a series of mechanisms that make movement possible which we know fully and separate from each other. On the contrary we find that movements seem to come of themselves, even when we are apparently responsible for the final result, and are content with that result when it is attained. The antiquated theories and the theories of the popular mind were inclined to say that there was a separate force or faculty called the will which determined how a movement should be made. This theory was so vague as to explain nothing and has long been given up for a more detailed analysis. We use the term *will* now only to describe the entire process as when we say that a man has a strong or a weak will. This means merely that the individual as a whole is effective or ineffective, is difficult to change when once he has started on a course or is easily influenced. No one regards it today as really describing an act or the way it is performed.

All of the modern theories assume that movement is the product of the sensory stimulation, that is applied to the man preceding the moment of action, and of the previous influences that have worked upon him. Of these one can hope to detect only the effect of the stimuli. We are interested here primarily in the cases in which the act follows upon a thought or memory process, what we call ideo-motor action as opposed to the sensori-motor action which is characteristic of reflexes. Sensations are also involved in the ideo-motor form of action. Sensory stimulation usually suggests the idea that immediately determines the act and also controls the movement as it is executed step by step. If one raise the question what it is that really brings about the movement when you speak a word, move a piece in a game of chess, or make a skilled shot at billiards, we have to distinguish between the immediate causes which control the single movements and the general aim or intention of which these movements are the effect.

Single Stimulus *vs.* General Situation. — The explanations of movement have been divided into two groups. One attempts to find the explanation in the stimuli or sensations which precede the act. The other sees the movement as one part of a complicated situation or complex. The difference lies mostly in emphasis, with the evidence growing that no single influence can be regarded as alone effective. After the notion of a separate will that was assumed to control action was abandoned, a theory developed that some one sensation or one form of idea was the real cause of movement. The form of sensory impression that was most frequently chosen was one of the proprioceptive or kinæsthetic sensations. The first suggestion was that a man moved a member whenever he had a definite reproduction of the way the member would feel as it moved. This theory was usually formulated in a rather less specific form. It was assumed that the man thought first of moving in general or had something suggest an end to be attained, and that this idea in some way suggested the memory of the feeling of the old movement, and then that movement was released. Careful examination of the events that preceded movements showed that the proprioceptive sensations were not an invariable accompaniment or antecedent of action. They are sometimes present, but movements may be made without them and they may also be present without movement. It is also evident from chance observation and experimental introspection that other sensations are also frequent antecedents of movement, but that no single form of sensation is essential.

Movement Grows from an Entire Situation. — An explanation of why one moves must be found not in any single antecedent or cue but in what the Gestalt School would call the whole system. That again is wider than the single unitary whole. The sensation which preceded is determined by the context present and past, and whether the sensation shall be followed by a movement also depends upon the situation into which it comes. One can find analogies for the relation between most of the ideational processes and movement. When a situation presents itself that has usually led to movement, movement follows immediately. The same idea may be present in another setting and no movement results. Try to think how you place your lips when you say a word, and if you are in a class or in company no movement will take place. If you are alone you will probably speak the word and feel the actual sensation. The presence of others inhibits the actual expression. The same dependence upon a situation is to be noted in more familiar situations.

Factors in Initiating Movement. — The total situation which may be said to determine movement may for convenience be analyzed into a number of subordinate elements. The most general aspect may be regarded as the intention. The intention in controlling action is much like the meaning in the thought processes. One appreciates the end that is desirable but may have no definite picture of the movements that are necessary to realize it. This intention is most prominent in movements which one desires to make, but has not yet completely learned and in movements that have become completely automatic. One plans to make a new type of movement and then must by trial develop the series of movements which will attain the end. On the other hand to have the general intention of mailing a letter or going to a familiar place for dinner is all that is necessary to have the sight of a mail box or of the particular eating place start the suitable movement. The general intention is a preparation for the specific acts. In simple or thoroughly familiar movements that intention is all that is necessary to initiate the movement.

Sensation and Movement. — The effect of the intention frequently expresses itself through the arousal of specific sensations which may be regarded as the more specific directors of the act. In learning, a movement comes to follow directly upon the presence of sensation or idea. Afterwards whenever that sensation presents itself the movement follows. As one rises for a walk the sight of a cane or a hat immediately causes the movement towards it and the movements of the arm and hand to take it. These movements are under the control of the general purpose of the walk, but the specific initiative comes from the particular sensation or idea. The intention starts the series of connected images in certain cases and these images precede each of the part movements of the act. The real causal effect is to be regarded as due to the corresponding connections in the nervous system, but the sensations or images accompany the activity of these nerve tracts and we are aware of the stages by these accompaniments. The different conscious processes are effective only as parts of the general situation, but they do represent important phases of the total. That the sensation or the nerve process which accompanies it is effective in controlling movement is seen from the fact that frequently thinking of an act that is not intended may be followed by a movement that disturbs the results. To have something suggest a word that is not in harmony with the purpose of a speech may cause that word to be spoken and destroy the meaning of the statement. Suddenly catching sight of a spot on the tablecloth may make the finger move to it and embarrass both the individual who makes the movement and the hostess.

Interaction of Purpose and Sensation. — While the general intention or purpose ordinarily dominates the effect of the sensation and image, at times a sensation becomes dominant that is not in harmony with the purpose. Then the movement is controlled by the sensation and destroys the effect of the general intention. Thus, if one is making a golf stroke and suddenly permits the bunker immediately in front to catch attention, the ball goes into the bunker in spite of the good general intentions of the player. In a baseball game, in the same way, if some object other than the point at which the ball should be thrown is attended to, a bad play is fairly certain to result. Even the attachment of a *not* to an idea does not always prevent the idea from affecting the act. Langfeld[1] found that in experiments which consisted in moving a wire along a groove, endeavoring to avoid touching the sides, the experimenters were more likely to touch the edge if they were asked not to touch it than if told to keep the wire in the middle of the groove. Attention to the side induced a movement toward it in spite of the intention to avoid it. Within limits, trying not to do a thing has the same effect as trying to do it. This is particularly true in acts of skill and of movements only partly learned. It is true in general that an intention of the more remote sort is frequently conquered by an idea of a specific movement, even if that be directly contrary to the intention. The effect of sensory stimulation may also be seen when an entirely extraneous sense impression breaks into the connected series. A sudden stimulus that comes in the course of an attempt to make a difficult movement will frequently disturb or destroy it. A sudden loud noise or bright light spoils a delicate line with the pen, or the aim of a rifle, or a drive at golf. Not the meaning alone, but that, together with the idea or object that holds attention, or the sensory stimulus that forces its way into consciousness, really directs the movement.

The Control of Movements. — We have seen that movements are determined in their immediate course by the general intent or purpose, and by specific sensations. These as the most prominent factors in the total situation may be regarded as the incentives to action. They are spoken of as initiating the movement. All during the act other sense impressions exert a control upon the way the movement shall be performed. James divided the sense impressions that directed the movements into two groups which he called the remote and the resident sensations. The remote sensations fall into the Sherrington group of exteroceptors while the resident coincide with the proprioceptors. Both influence the movement reflexly. That is the impulses from the sense organ act upon the moving member and combine with the general intention or specific sensations to determine what movement shall be made. The man who makes the movement is not conscious of their presence. This is especially true of the resident sensations. As a finger is moved with the eyes closed, the kinæsthetic sensations are constantly coming to the cortex and sending out reflexes which serve properly to direct the movement and to adjust its force and extent. They are most easily demonstrated by their absence. In tabes the motor nerves are unimpaired, but the posterior columns in the cord which carry the kinæsthetic sensations are destroyed. A characteristic symptom of the disease is inability to control movements. When the eyes are closed, the patient is not able to bring thumb and finger together accurately and still less to bring two fingers together in front of the face with a single sweep. Locomotor ataxia with its irregular gait is one form of the disease.

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[1] H. S. Langfeld, "Movement under Positive and Negative Suggestion," *Psychological Review*, vol. 20, p. 459.

Remote Sensations. — The remote sensations are also active in detecting and correcting any departures from the intended course of action. Thus, when writing, if the hand starts to make a crooked line, the deviation is at once seen, and the eye directs the pen back to the right path. The influence of the eye is not appreciated; but, if one attempts to write with the eyes closed, it is at once apparent that an important correcting force is lacking. Sensations from the ear act in the same way in governing speech and the tone in singing. Experiments show that most singers, some of them among the most famous, are not able to strike the correct tone at once, but make an attempt, are quick to detect that the tone is too high or too low, and so adjust the pitch to the correct one. The violinist, too, does not estimate the position of his fingers on the string by the kinæsthetic sensations, an estimation that would require marvelous accuracy, but approximates the position first, and then, as the bow begins to give the tone, he adjusts the length of the string until his ear tells him that the tone is correct. That the remote sensation is essential is shown by the fact that the deaf cannot speak without special training. The training consists in teaching the patient to control the voice by kinæsthetic and tactual sensations instead of by the sounds that are used by the individual who hears. The deaf child feels the teacher's vocal organs, and keeps trying until he makes his own carry out the same movements. Or he feels with his fingers the bones over the larger cavities in the skull of the teacher and in his own and tries until both resound in the same way. The sameness of movement is at first recognized by touch, but with practice the kinæsthetic sensations from the vocal organs suffice. The control processes from both the resident and remote sensations become automatic, so that one notices neither the sensations themselves nor the fact that they exercise control. The sensations from the eye guide the hand reflexively, or with as little thought as is required for the reflex.

Another striking case of reflex guidance of this sort is that exerted by the static sense, the stimuli from the vestibular branch of the auditory nerve. The stimuli from the static sense as was seen in the earlier chapters, excite the motor centers in the brain stem, particularly the cerebellum and the roots of the motor oculi nerves. These sensory nerves probably give no sensations, but nevertheless they guide the movements of the body as a whole, serve to keep the balance, and give rise to compensatory eye movements — the movements that keep the eyes fixed on the same point in spite of the movements of the head and body. The sensory impulses call out these movements continuously and often we have no knowledge that the movements have been made; certainly we have no appreciation of the fact that they produce the movements. The stream of impulses coming in through the vestibular nerves constitutes one of the important forces which control any movement of the trunk.

General Laws in the Control of Movement. — Any act, then, may be said to be the outcome of the appreciation of a situation that requires movement. The immediate incentive is usually some object or idea that for the moment holds the center of consciousness. But this incentive is seldom the picture of the movement to be made; more frequently it is some idea of the end to be accomplished. If the movement is relatively unfamiliar, it is an idea of some immediate act; if very familiar, a more remote end usually is dominant. The intention does no more than mean the movement; it seldom recalls it in sensory terms. The movement is always guided by the resident and remote sensations. These adjust it to the conditions of the moment.

When a movement has been repeated sufficiently often to become automatic, attention is needed only at the beginning. The act is started, and attention then turns to something else; the association between the movements and the resident and remote sensations serves to carry it to its goal. Thus, in walking on a familiar course, one merely decides to go to a certain place and, when once started, one step starts the next, always under the control of the remote and resident sensations. The visual stimuli lead to the avoidance of obstacles and guide in making the necessary turns. Unless some new obstacle is encountered, one may go into a 'brown study' at the moment of starting and not realize again what is going on about until the destination has been reached. All movements or chains of movements, at first learned or joined together by effort and under the influence of a complete consciousness, tend gradually to lose more and more of the conscious accompaniments and antecedents. Finally, in more complex acts, they may start from some unnoticed stimulus; in the case of simple acts or a number of unified simple movements, they may be started by a single idea, may be initiated by a conscious process and guided to their end by habit without further consciousness. Associations between the movements themselves or between the resident sensations of one movement and the motor processes required for the next, take the place of all more definite awareness. Even in these automatic acts, there is guidance by a wide group of habitual connections between neurones, not at all appreciated by the agent.

REACTION TIMES

The Reaction Experiment as Instance of Movement. — One of the first and still a favorite experiment in psychology is the measurement of the time required for movement under different conditions. These experiments are valuable not merely because of the knowledge they give of the time required for different movements and for other mental processes, but for the opportunity they afford to study the causes of movement or the conditions under which movements take place. The experiments are conducted by automatically starting an accurate clock at the moment a stimulus is applied to the man who is to react and stopping the clock automatically when the movement is made. The instruments most frequently used in the laboratory register thousandths of a second (σ). In the simplest apparatus the clock is started when a sound is produced and will be stopped at the instant the man whose reactions are measured presses upon a key. In other cases the clock starts when a word is shown and will be stopped when the reagent opens his lips or by the air expelled in speech.

The Stages of the Reaction. — The reaction process gives an indication of the fact that a movement is always the result of the preceding events that give it a setting. Here the fact that the observer reacts at all is due to the preceding instructions and his willingness to coöperate in the experiment. More detailed instructions and the attitude that the observer takes by chance and in response to the directions influence the time and, in experiments which give a chance for variation of response, also influence the character of the response. To bring out this influence, Ach, who performed many experiments upon reactions, divided the period of the reaction into three parts. These were the fore-period which immediately preceded the experiment, the time of the reaction proper, and the after period. The fore-period is the time of preparation. Always in the experiments a signal to be ready is given about two seconds before the stimulus. Freeman has shown that the ready signal is immediately followed by a tension in muscles of the arm and in the body muscles generally. Accompanying this is a concentration of attention upon the signal to be given and the general sensory as well as motor preparation. Without this preparation the response requires much more time and the durations are much more variable than with it. Evidently, much of the work of the reaction is accomplished before the stimulus is given.

Specific Preparation. — The most thoroughly investigated of the more special types of preparation with the simple reaction is (1) preparation for the reception of the stimulus (the sensory reaction) and (2) preparation for the movement of the response. This was noticed early in the course of the development of the experiments by Lehmann. Lehmann found that the response required approximately 100 thousandths of a second (σ) less if attention was directed to the movement than if it was directed toward the stimulus. At first there was bitter controversy as to whether the difference must be exactly 100 σ and some even questioned whether there was a marked difference between the sensory and the motor reaction times. Now most experiments show a difference but in varying amount. More important is the explanation that may be given of the difference. Probably that the sensory reaction is slower is due to the fact that if attention is directed to the stimulus the motor preparation is not so complete as it is when preparation is made for the movement. This old explanation has been confirmed by results of Freeman which indicate that the muscles of the arm that is to react are more tense when attention is upon movement than when it is upon response. The tension is more diffuse, it spreads through more muscles in the sensory type of adaptation. Physiologically this means a readiness to react with any muscle rather than with the right hand alone, as in the motor form of reaction.

Simple Reaction Times. — The time needed for the simplest reaction has been studied in connection with the sense that is stimulated rather more than with the member that is moved. The quickest responses are made to sound. These times vary from 120 σ to 180 σ for different individuals and different investigators. The tactual impressions are in almost the same range, from 117 σ to 183 σ. The time required for response to pressure is less than to cold, and warmth and pain take longer than cold. Reaction times to sight are considerably slower than are those to auditory or skin sensations. They require from 150 σ to 225 σ. Difficulties in devising apparatus have prevented measurements of reactions from the other senses. Rough results indicate that taste and smell are slower than the other senses. These simple reactions indicate from the observational side that in a suitable condition of preparation, all that is involved in the response is the mere awareness of the stimulus. The instructions, the preliminary preparation at the ready signal, and attending make the stimulus the only essential to the release of the movement. Frequent repetition increases the readiness and makes the response still more automatic than at first. Up to a point the responses become quicker with practice.

Complex Reaction Times. — More light upon the voluntary processes is thrown by the experiments in which more than one response is possible or some alternative process is necessary before the response is made. Whenever alternative responses are possible, the time is increased. The first addition to the simple reaction is offered by the cases in which one stimulus must be distinguished from two or more before a response is given. When red or green may be shown and the observer must respond only to red, the simple reaction is increased from 180 σ to 200 σ or so. As the number of colors between which one may discriminate grows, the time is increased. Larger more familiar objects are cognized as quickly as smaller objects. Cattell found that a short word could be seen as quickly as a single letter. These experiments in which the subject is asked merely to be sure that he has seen the word or heard the sound before he responds are known as cognition reactions. Closely related in purpose and different from them only in the method of assuring cognition are the discrimination reactions. In these the observer must make one movement when he sees one color and another when he sees another. In a very common form he will react to red with the right hand and to green with the left hand. Discrimination times are longer than cognition times, possibly because there can be no premature reactions without being detected. They also increase markedly in length as the number of possible objects is increased. Where each numeral was assigned to a different finger, 276 σ was required when there was discrimination between two figures, and this increases regularly to 588 σ when there are ten figures and ten fingers involved in the responses. Discrimination times are longer when there are slighter differences between the stimuli. The time required to respond is an indication of the complexity of the response and of the difficulty in distinguishing the stimuli. These were earlier called choice reactions, for it was assumed that a movement must be selected after the discrimination is completed. This designation has been abandoned in later times since it seems, in these simple cases, that there is no separate act of choice.

Association Times. — The more complex mental processes can also be measured by the reaction method. Simplest and most frequently made are measurements of the time required for associations of different kinds. In these experiments a lip or voice key is used. The observer is asked to speak the word that is aroused when a first word is shown. The time is measured from the exposure of the stimulus word to the speaking of the associate. The times required for a response vary greatly with the conditions under which the responses are made, the closeness of the connection, the frequency with which they have been repeated together, — in short upon the strength of the connections. Wreschner states that they vary from some 325 σ to 2 seconds or more. The fewer the possible associates the shorter the time. Thus Watt found that when individuals were asked to name the class in which the object designated by the stimulus word belonged, less time was required than to give an instance under a class. If dog was shown with the request to name the group to which it belonged, to say *mammal* required less time than to say *Spitz* when asked to name a breed of dogs. The influence of the task set in advance of showing the word was very striking. The range of associates recalled corresponds accurately to the task set or to the attitude. At first the problem or task may be definitely conscious but it soon falls completely into the background and is taken for granted.

Influence of Direction upon Choice of Associates. — Tasks may be given of any kind and with very different degrees of definiteness. The very fact of taking part in the experiments is a factor in determining the more general reactions. This acts upon the interpretations of the tasks set. The specific tasks may vary between being told to say anything at all when the word is shown and being drilled upon an association of nonsense syllables and asked to give the second in the series when the first is shown. The completely free association takes considerably more time than the completely determined. The task may be set in hypnosis (Ach) and be effective in the experiments of a waking series.

Ach tested the effect of having a very strong connection work against a task. He had observers repeat a pair of nonsense syllables until one recalled the other almost invariably. He then showed the first syllable and asked that the syllable that came to mind be spoken. Sometimes the second syllable rhymed with the first, sometimes the second was the first reversed and sometimes it had no relation to the first. When the first syllable was shown, the task was merely to speak the first syllable that came. In other experiments the subject was shown the syllable with the request to make a rhyme or to reverse the syllable shown. Ach was interested to determine what happened when a syllable came that had been learned with its rhyme and the observer was asked to reverse it. He estimates on the basis of his results that the effect of the task is equivalent to from 100 to 120 repetitions. That is, the task set will dominate over the effects of 100 repetitions. Thus if one syllable has been followed by a rhymed syllable 100 times and then the syllable be shown with the request to reverse it, the probability that the syllable that presents itself will rhyme is just equal to the probability that a syllable with the letters of the first reversed will present itself. This gives an approximate indication of the relative influence of the task as opposed to strength of connection from repetition. The times required when the syllables had been learned in accordance with the task set at the moment of recall were from 500 σ to 1000 σ. When there was a conflict between the type of response asked for and the previous repetitions, the times were approximately 100 σ higher. Both showed wide variations.

Wide Organization of Experience Controls Movement. — The evidence from reaction time experiments indicates that a movement is the expression of many factors, not of a single mental or physical process. The total situation in which an individual finds himself determines the movement. The observer comes to the laboratory with the intention of taking part in an experiment. He receives directions as to what he is to do. In each reaction he is controlled by the special task that is set him, by the results of previous reactions, and of the more general habits. The ready signal, the muscular preparation that goes with it, the task assigned for the series all are as much a part of the determinants of the movement as the immediate stimulus itself or the ideas and sensations that come immediately before the response. The times vary with each of these elements. We may well assert with the Gestalt group that what counts is the entire organization of the man at the time, rather than any single element, or any sum of separate elements. If we transfer these results to the acts of everyday life they indicate that any act is not determined by a single preceding experience, but is the outcome of a complete organization of experiences.

CHOICE

Choice and Motives. — A problem which is frequently raised in this connection is how one chooses when it is felt that two acts or lines of conduct are possible. The study of reaction time has already shown that usually the responses are made automatically. The stimulus in the particular situation and with a definite purpose or task brings about the movement without any intervening mental process. As was said above, while choice times were once given a separate place in the reaction time experiments, the term has been dropped in recent years, because the acts that had previously been classed under that head were seen to be no more than discrimination processes. But in some instances two opposed acts are felt to be possible, and it is necessary to choose which is to be performed. The actual act of choice is relatively simple. It amounts merely to giving one intention free play and checking the others. The only mental content consists in attending to the movement to be made or the result to be attained. When the choice or decision is made long before it is to be carried into effect, it consists frequently in outlining the course of action in words or in some idea — some concept perhaps. When the time comes, the stimuli present lead at once to the act. The only new problem in connection with choice is what gives rise to the intention, why one course is chosen rather than another. This depends upon the selection of one or the other of the possible ends present to consciousness. The explanation lies finally in the laws of attention and association, and offers little that is new. The deciding factors are the subjective conditions of attention and of association. One seldom regards as choice the decision determined by objective factors alone.

The Task or Mental Attitude in Choice. — The importance of the situation, set or purpose has been frequently mentioned. The results of Ach in other reaction time experiments bring the effect into clear relief. In one set of experiments he asked his observers to move the right finger when a letter *E* was shown, and the left when the letter *O* came. The times required for making each movement were measured. It was found that no real decision was made after the cards were shown, but that the movements were made at once because of the previous preparation. This is evident from the fact that more time was required when the subject was left free to react with either finger than when the finger to be moved was prescribed. In the latter case part of the preparation for action had been completed before the movement began. It was in these same experiments that the control of the arithmetical associations was studied. When two numbers were shown one above the other and the observer was told in advance to add or subtract, the result came at once or after a relatively short time. When, on the other hand, the numbers were shown with no instructions, the resulting process was much delayed, and the observer had a chance to study the process of choice. The task or purpose serves to control choice just as it does to determine association. The effect of the purpose is replaced by the situation and the general intentions of the moment in many choices of everyday life. It is this that leads one to take an umbrella when the sky is cloudy, and a cane when it is clear, as one goes past the rack in the hall; to choose a serious volume when one comes into the study in working hours, and a novel or the newspaper in the period just after dinner. In all these things, the choice, while apparently undetermined, is guided by the general attitude and the environment.

More Remote Influences in Choice. — In more complicated and important instances of choice, the final selection is similarly determined, but the controlling influences are much more numerous. The final release comes with thinking of the end to be accomplished, with the full belief that the act is to be carried out. The antecedent processes are much like the balancing of decisions in doubt before full belief presents itself. First one alternative is thought of, then another. After these alternations have repeated themselves several times, one finally dominates, is held in mind, and the others are by that very fact excluded; the decision is made. The forces that favor the possible alternatives are to be found in the inherited tendencies on the one side and the social forces on the other. They constitute what are called the motives. The motives are themselves ordinarily quite largely out of consciousness. One knows only that one course of action or another is preferable but has no knowledge why it is preferred. Carrying this back, we see that of the possible lines of conduct the one is chosen which proves most attractive. Why it is attractive is determined by natural endowment and education. There is no trace of what is commonly called will.

WILL

Is There a Separate Act of Will? — Closely related to the problem of choice is the question raised at different times in the history of psychology as to whether there is a special act that releases the movement after the choice is made. If it exists it would correspond to what the earlier man called the process of will. The earlier writers, always tending to discover a separate faculty or force for each of the words in common use, hardly questioned the existence of the 'fiat' of will, something which was an actual force in decisions and an incentive to action. As the direct examination of mental states began to take the place of speculation with only inaccurate observation, fewer and fewer men were able to discover this peculiar state. Instead, an ever-increasing number of authorities found the final cause of action in an idea that was attended to, in an idea of the movement with the belief that it was to take place, or in the feeling qualities preceding or accompanying the idea. As more and more work was done upon the analysis of the consciousness preceding action, the less was there found that was peculiar to this state.

Experimental Investigation upon the Will Problem. — Modern investigators, Ach and Michotte and his followers, have revived the old doctrine in a slightly new form. In certain of his more complicated reaction time experiments, Ach asserts that it is not merely holding the idea of the movement in the center of consciousness that evokes the movement, but that in addition to this it is necessary that the self become momentarily identified with the movement to be made. At the moment the self is thus identified with the one alternative, the choice is made, and the action is determined. A somewhat similar statement is made by Michotte in connection with a choice between operations upon numbers as a result of experiments carried on by himself and Prüm.[1]

In an experiment conducted with Barrett,[2] measurements were made of the time required to choose between two liquids and to drink one of them. The liquids represented different degrees of pleasantness and unpleasantness. They were tested in advance and designated by letters that should have no associations other than those which developed during the experiment. The observer was to watch carefully what preceded the decision and to determine if possible what was the deciding factor in his choice. In this series of experiments the element of voluntary choice seemed less important. In fact, Barrett regarded the result as proof that choice is made and executed without any peculiar new activity that could be designated an act of volition. Instead, he found that one arranged the tastes as they were learned in order of agreeableness; and, when they were presented, the value on this scale was an immediate guide to the choice. The whole choice was completed when the liquid had been given its letter and place in the series. He finds that the determinants of the act are approximately the same as those we have enumerated above. Michotte [1] in reply reasserts his belief in a pure act of volition which must intervene in all acts of choice, whether related to action or not, and after the choice is made must again intervene in the execution of the act involved in the choice. He believes that the selection of one from a group of liquids of known value tends to render the process more automatic, and that this accounts for the smaller part played by voluntary choice.

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[1] Michotte and Prüm, "Étude expérimentale sur le choix volontaire et ses antécédentes immédiates," *Archives de psychologie*, vol. x, p. 113.

[2] E. B. Barrett, *Motivation Tracts and Motivation Forces*, 1911, New York.

'Will' the Whole Man Active. — This difference of opinion between Barrett and Michotte is typical of the opposing possibilities in the explanation of a voluntary act. On the one hand, emphasis is placed upon the more remote underlying conditions; on the other, upon the necessity for discriminating between the alternatives by holding in mind first one of the motives and then the other, and making a positive choice between them. On Barrett's interpretation, the motives are effective because they appeal to certain instinctive or habitual and social traits in the man's nature. On Michotte's, the final determinant of action is a force or active element which serves to make the choice and release the act. On the second alternative, the active element is hard to describe, is found by only a few men and by them only on rare occasions. Although prominent in popular discussions, the observation of untrained men, who constitute the chief advocates of its existence, is unreliable. Much of the feeling of will that the popular mind accepts as evidence of a separate faculty is made up of strain sensations, which even Michotte would not regard as an essential part of his voluntary act. Viewed from the practical side, it makes very little difference whether this active element is or is not assumed. All would agree that when the will acts, it acts in the light of the motives; it is an expression of the nature of the man; and that in turn is dependent upon his instincts and training, his immediate purposes and general ideals. The only question remaining is whether these act directly in the execution of the movement, or whether they act first upon the will, and that in turn determines the act. In view of the uncertainty as to whether the will activity exists and what it is like if it exists, it seems simpler and safer to omit it as superfluous, and to assume that the observed conditions determine action directly. On that conclusion, 'will' is a term to designate the whole man active, or a word used to distinguish between automatic acts and those that imply choice and are controlled by the system of purposes. It does not necessarily imply any new and distinct entity.

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[1] Michotte, "À propos de contributions récentes à la psychologie de la volonté," *Ann. de L'Institute Super. de Phil.*, no. ix, *Études de Psychol.*, vol. i, pp. 193–233, 1912, Louvain.

The Will and Freedom. — This result suggests the old problem of the freedom of the will, and it may be considered here, in spite of the fact that it is at present regarded as belonging to ethics rather than to psychology. At first sight it seems a logical inference that, if man has no will, he cannot be free. This defines the will too narrowly; it would restrict it to the something that we could not find standing between the motives and the act itself. If we regard the will as the sum of the conditions which lead to action or to spontaneous action, or even more generally as the whole man active, the question cannot be disposed of so summarily. From this point of view, the answer as to whether the man is free depends very largely upon how we define 'the man.' We have seen throughout that many of the determinants of all mental action, and particularly of voluntary action, are to be found in man's instincts, in the way he has been affected by education and by the society in which he has lived, by his nature and nurture in the broadest use of both terms. If one is to oppose these external forces to the man himself, a good case could be made for the statement that the man is largely determined by forces outside of himself. But if one make the division between the man and all of these factors, if one take away from the man all that he has learned, all the controlling forces of society, and all of his natural endowments, his instincts and innate tendencies, only a rag of a man would be left; most that is peculiarly himself would have disappeared. It is altogether more satisfactory and truer to the facts to regard these influences as included in the man, to think of him as in part at least the product of his heredity and environment, for this is the man as we know him. To divide the controlling forces into two groups, one external, the other internal, one environmental, the other personal, has never been attempted; and no two psychologists agree where the division would come. Oppose the man as he is to external forces, and he must be said to control his own acts. They are the expression of the whole man, and he is free to do as he chooses. One may put the solution of the problem in another way by asserting that man is free to do what he desires, but his desires are the outcome of his instincts and environment and over these he has little control. In other words, the question is largely one of classifying facts and of defining terms. The facts themselves are accepted by all.

Freedom in Practice. — In practice, acceptance of one theory or the other makes little difference. What one generally does is to think of one's self as a free agent in every respect, and of every one else as rigidly determined by environment and education. It is only when one takes the objective attitude toward one's own acts, that one tries to trace them to their conditions. Probably this assumption works best in practice. The new tendency to regard man as the product of his environment has led to improvement in social conditions, to the recognition that mankind in the mass may be improved if one will but begin with remedying the fundamental conditions of living, that changing his environment is better than talking to him. Improvements in education, in housing conditions, and all the multitude of laws for bettering the environment of the poor, are due to the growing tendency to regard the environment as responsible for the actions of others. On the other hand, the belief in one's own freedom probably gives added initiative and increased recognition of individual responsibility that would be lost were one to think of one's self as a mere link in the world chain. However, the instinct of self-assertion is too strongly embedded to permit acceptance of any theory to change the aggressive individual into an inert one.

Environment and Freedom. — Probably the difference in the attitude towards crime and the criminal more clearly represents the effects of the two theories. On the older free-will doctrine, the criminal was altogether responsible for his acts. He would or he would not carry out each act. There could be no control of crime, because no one could tell when an individual might decide to commit one. The other theory looks upon the criminal as the product of his heredity and of his environment, in much the same way that a sick man is the victim of circumstances. In the extreme form, the whole problem is one of removing the causes of crime, as the control of health is one of removing the causes of disease. The attitude toward punishment changes similarly. If the man is free to be a criminal or not to be, the only value of punishment is to get even, to measure the crime and make him suffer as he has made others suffer, 'an eye for an eye.' On the other theory, punishment is merely a means of reform. It gives the criminal a motive for refraining from crime, it may give him a chance to form new habits, or even to learn some new trade or obtain some other means of support that shall make crime unnecessary. In the worst cases, it is a protection to society by removing the criminal to a place where he can do no harm. In any case the idea of vengeance, essential to the older view, does not enter. When it is considered that a large percentage of criminals are mentally deficient, have an intelligence no greater than a child of ten, the modern theory has even more weight. The final outcome of the two theories is approximately the same; but the methods of inflicting the punishment and the attitude while carrying it out are altogether different. On the whole it may be said that the problem of the freedom of the will has been outgrown rather than solved. The present attitude toward the world and man's place in the world leaves no room for the problem, instead of deciding which solution is the correct one.

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CHAPTER XX

WORK AND FATIGUE

One of the important problems of action, for practice as well as theory, is the effect of work upon the individual's capacity to continue working. The decrease in capacity for work as a result of work we know technically and popularly as fatigue. Fatigue is a result of all but the easiest and shortest work. We ordinarily speak of mental and physical fatigue, although it is questionable whether fatigue ever is anything but physical. There is no bodily work without some mental direction, if we use the term popularly, and little or no mental work that does not involve movement, so the distinction is not of great importance. The distinction applies only to the nature of the accomplishment, not specifically to the nature of the fatigue itself. To work to the best advantage for the immediate task and to avoid the after-effects of excessive work, one must know something of the laws of fatigue. Possibly it is better to state the problem at first as one of determining the course of decrease or increase in capacity during a period of mental or physical work.

The Curve of Work

Changes in Accomplishment. — In the ordinary work period the effect of fatigue is not immediately apparent as it is obscured by the influence of practice, the changing incentives to work, by boredom and habits which prevent working to the maximum of capacity. A number of records have been kept, beginning with Kraepelin and his students, of the way accomplishment varies during work periods of different lengths. In many industries records have been kept of the way output varies during the periods of the working day. All the results available agree in certain striking respects. In general the variations in the amount accomplished are slighter than might be expected, but are consistent. Work usually starts at a high rate and falls off quickly, — the initial spurt, it is called. There is a gradual increase in output for a considerable portion of the work time, then a gradual decline, and an increase just before the end of the period. If a rest period is introduced, work afterwards will increase in rate if it is neither too long nor too short. If the rest period is too short it will either have no effect or will decrease efficiency; if too long, there will be a decrease in output afterwards, followed by an increase.

Analysis of the Curve of Work. — Kraepelin early gave an analysis of the curve of work into a number of components. Some are effects of work which tend to increase capacity. Fatigue is the one factor which consistently diminishes capacity, or possibly it is better to say that diminishing capacity as the result of work is known as fatigue. Work also tends to increase the capacity for work. This tendency is known as *practice*. Practice increases more rapidly at first, and then less rapidly. Practice is allied to habit as an adjustment of the nervous system to a new situation, and constitutes what we call skill. It is assumed to reach a maximum at some time, although it is probable that new conditions of work or a new attitude towards work may produce an improvement even after long periods of training. It can be said, however, that practice will make work more easy and effective, that it increases rapidly at first and then more and more slowly as work is continued.

The initial fall and terminal increase are due to a temporary *incentive*. The individual begins with a firm intention of doing his best, and does so for a few strokes. This special incentive wears away quickly, and with it there is often a fall in output immediately after work begins. At the end there is a similar speeding up to make a good showing for the finish. This is not necessarily conscious, but the very fact that the end is in sight serves as an incentive, and speeding up takes place automatically, just as the goal in a race calls out a final increased effort. A fourth factor is *inertia*. In most types of work it takes a little time to reach the best speed; and when once started work tends to go on of itself. One of the strongest reasons for assuming the presence of inertia is that a rest period tends to decrease the rate of output. The decrease in output due to loss of momentum is compensated for by the rest if the stop is of the right length. The longer the break, the greater the loss of momentum.

The Curve of Work in Industry. — We have many indications that output in industry shows the same tendencies as

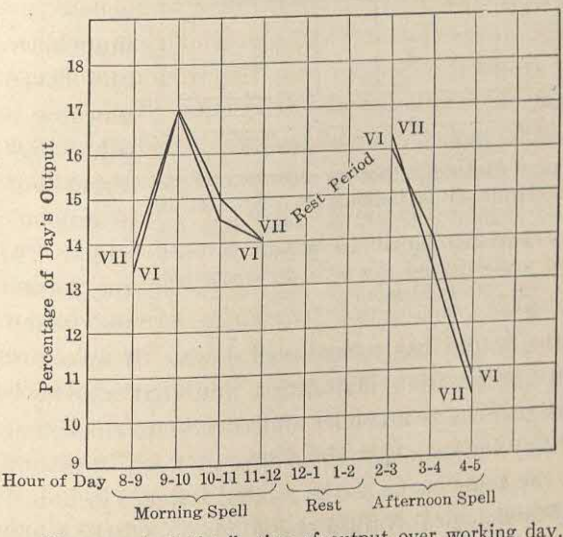

FIG. 113. — Shows typical distribution of output over working day. Work of Italian typesetters. (From Muscio.)

the curve of mental work in continuous adding as used by Kraepelin. A record kept of the output of typesetters for different hours of the day shows a rapid rise for the first hour and a half, then a decline for the remainder of the morning. After a two hour rest at noon, efficiency rose almost to the peak of the morning curve and then declined sharply until closing time. (See Fig. 113.) Reports of accidents from different trades and countries give confirmatory evidence. A study of the periods at which the greatest number of accidents occur shows a maximum between ten and eleven in the morning, and another high point about four in the afternoon. (Fig. 114.) These are the times when the other chart shows the output has turned well down. If we assume that accidents occur from inattention and that alertness wanes with fatigue, the two results and curves are consistent. Together they indicate that the course of work in mental tasks follows the same curve as the related fatigues in industry.

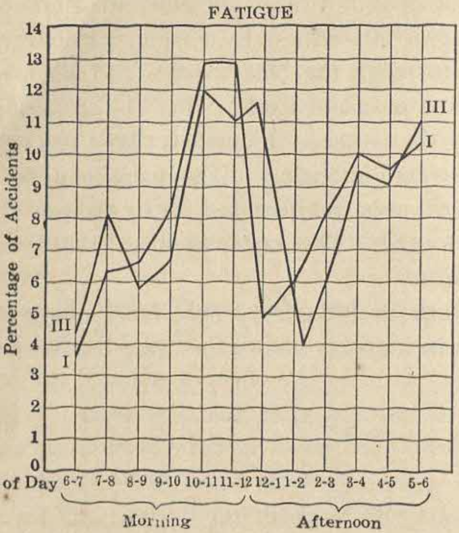

FIG. 114. — Shows the time of occurrence of industrial accidents, (I) in Germany in 1887, (III) in Lancashire, England. It will be noted that the periods of increased output are periods of small number of accidents and *vice versa*, by comparison with Fig. 113. (From Muscio.)

The Physiological Nature of Fatigue. — Of the factors that determine the curve of output in work, fatigue deserves the most consideration, since the others are incidental to phenomena already discussed. Fatigue is to be referred to several different causes and may be simulated by various other conditions. Sometimes it is more specific, sometimes more general. Some men have insisted that what passes for fatigue is really merely disinclination to exertion. It is well to begin with the most specific evidence and to pass on to the more general. The most thoroughly studied phase of fatigue is of the muscles. Something of muscular fatigue must certainly be present in all the cases that are classed as fatigue. Some authors have argued that this is the only element in fatigue. The first studies of muscular fatigue were made on the large sartorius muscle of the frog. The muscle with its nerve may be dissected out and hung so that the muscle supports a lever, which writes the contractions of the muscle upon a revolving drum. Stimulating the nerve produces a contraction of the muscle. At first the contractions increase slightly in extent. This is explained as due to the stimulating effect of the waste products that accumulate in the muscle. Later the contractions diminish in extent even when the stimulus remains the same, and finally they cease. The causes of fatigue in this simple system are found first in the breaking down of the point of connection between nerve and muscle, the endplate. This is shown by the fact that after the muscle can no longer be stimulated through the nerve, it will still respond when stimulated directly.

If, after stimulation of the nerve no longer produces a contraction, the stimulus be applied to the muscle, contractions will begin again. They in turn gradually diminish in extent and will finally completely disappear. This incapacity of the muscle is due in part to the accumulation of waste products, as can be seen from the fact that after the muscle has once stopped acting through fatigue, it will respond again in almost full amount after it has been thoroughly washed in a dilute solution of salt. There is also exhaustion of the stored nourishment in the tissue, but this seems to come later than the inhibition of the capacity for action, due to the accumulation of waste products. In addition to the waste products that accumulate in the muscle itself, investigations of animals working as wholes indicate that toxins appear in the blood and may be carried to any part of the body and affect tissues of all kinds. An old experiment of Mosso showed that blood transfused from a fatigued dog to a rested one produced in him many of the effects of fatigue. While later experiments do not altogether confirm the Mosso method, other methods do indicate an accumulation of toxins in the blood as a result of continued work. Piéron has announced that a sleep-producing substance develops in the blood of a working animal that induces sleep

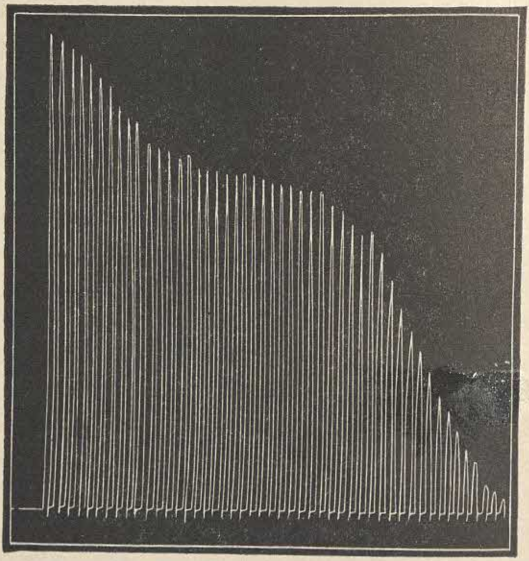

FIG. 115. — The vertical lines indicate the relative distances through which a weight of 6½ pounds is pulled by the middle finger of the right hand. Contractions were made at intervals of two seconds. (From Howell's "A Textbook of Physiology," 5th edition.)

when introduced into the circulation of an animal of the same species that has been resting. The toxic effects seem to be diminished or overcome by the secretions of adrenal glands. Animals in whom the glands are removed indicate a much greater effect of work, and are also more influenced by injections of fatigue products than are normal animals.

Secretion of adrenalin would follow the emotion that is aroused by work and would stimulate the liver to secrete glycogen. This in turn supplies nourishment to the muscle. The increase in circulation due to adrenalin would have the same effect.

Changes in Neurones with Fatigue. — Numerous workers have reported changes in the cell bodies of the neurones after long continued work. Of the earlier workers Hodge reported that at night after a day gathering honey, the nuclei of the ganglion cells of a bee were much reduced in size and the walls were much wrinkled as if in collapse. Later writers have produced changes in the cell tissue which responds to staining (chromophil bodies) by prolonged electrical stimulation of the ganglia of a cat. These changes in the cell bodies of neurones,

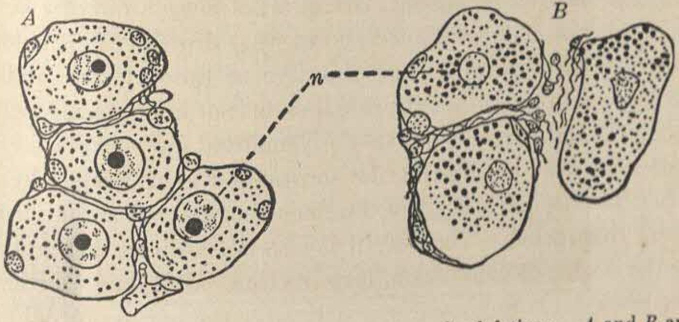

FIG. 116. — Changes in the nucleus as a result of fatigue. *A* and *B* are both from the spinal ganglion of a cat. *A* shows the resting condition; *B*, a cell after electrical stimulation of its nerve for five hours. The nuclei in *B* may be seen to be much smaller and to be very irregular in outline. (From "American Text-book of Physiology," after Hodge.)

the accumulation both in muscles and in the blood of waste products which act as poisons, the exhaustion of the tissues and of the muscles together constitute the physical changes in fatigue. These do not always act to reduce the capacity. In the isolated muscle, even, the first effect of fatigue is to produce unusually large contractions. Application to the muscle in small amounts of waste substances from another muscle increases the amount of contraction with constant stimulus; and the products of the muscle itself have the same effect. Fatigue products first increase the excitability of a muscle, and then diminish and finally destroy it.

Indications of Fatigue. — The problem of fatigue is complicated in practice by the fact that it is not always directly evident when a man is fatigued and to what degree. This holds whether we deal with the subjective or the objective indications. On the subjective side it seems not infrequently that when the individual is not specially unfitted for work, he feels listless or even has a marked disinclination to exertion. Yet, when an incentive is given, he finds that he can accomplish more than usual. The output is also not a direct indication of the degree of exhaustion, for sometimes after long exertion the work is continuing at approximately the normal rate, but a breaking point is near. This is especially true of mental work, in which few muscles are involved. These facts make it essential to seek definitions of fatigue. They must include recognition of the capacity for work at the moment as measured by the output, latent capacity, which can be measured, if at all, by some physiological index, and the later aftereffects of the work as shown by the quickness of recovery and in severe cases by the effects upon later health. Fatigue then is an effect of work which shows itself immediately in reduced output. It reduces the capacity for work at periods closely or more remotely following upon the work.

Fatigue Tests. — Various tests for the degree of fatigue have been suggested. The most usual is the amount of work accomplished in a given time. This is a good general indication, but has the defect that output sometimes goes down with little fatigue as at the initial period of work, and, still more important, output may continue at a maximum when the point of incapacity for work or rapid decline is near. Painter found in experiments on addition conducted at night after a day's work at general problems, that his output showed no decline over a long period and then would stop almost completely. Experiments on deprivation of sleep have afforded instances in which individuals could perform complicated tasks at the normal level when they were having delusions or near delusions that would mark the rested man as abnormal. In one famous early experiment on the effects of enforced lack of sleep, almost no effect was detected in capacity as measured by tests, but the man who conducted the tests suffered much of the remainder of his life from what was called a nervous breakdown and which may have been attributed to the prolonged lack of sleep. Lack of sleep and fatigue are closely related even if a distinction must be made between them. Probably no mental work could be carried to the point of serious injury unless it were of sufficient duration to cut down the usual amount of sleep.

Indirect Measure of Fatigue. — The indirect measures of fatigue that have been suggested and tested also fall short of complete adequacy, although some are useful. They have been suggested because of the inconsistencies between momentary output and later output mentioned above. Changes in the number of leucocytes have been noted after work. Griffitts and the author found, after the largely mental work of typewriting original material, a reduced blood pressure, a slowing of pulse and respiration and a decrease in the time a minimal light could be seen. Lewis found a decrease in the amount of glycogen in the blood. Steadiness of the hand was also greater after mental work. No single test or combination of tests has yet been devised which gives a satisfactory indication of the capacity for continued work. Needless to say one would be highly valuable did it exist.

Mental Fatigue. — Thorndike and others have questioned whether mental fatigue has a real existence. Thorndike bases his skepticism upon the instances which show that when an individual has apparently reached a high degree of exhaustion some special incentive will frequently bring the efficiency back to normal or above. He also supports his skepticism by the results of Miss Arai who on four succeeding days could add simple figures for ten hours without a break and accomplished about half as much in the last hour as in the first. Thorndike would explain all decrease in output as a result of boredom. The individual could work if he would, but is not willing to make the effort. A similar line of argument would show that many other conditions also have little effect upon the individual. Work at uncomfortable temperatures or in badly ventilated rooms proves by tests to be very little less productive than work under the best conditions. Probably the explanation is to be found in the compensating influence of incentive. The belief that a standard task should be accomplished in spite of fatigue or bad air stimulates to greater effort and this compensates in some degree for the decrease in general capacity. The fact that exhaustion comes at last and that the effect upon the general health is bad outweighs the evidence from a few cases of work with slightly reduced output.

Is Mental Fatigue Different from Physical? — A man who accepted the evidence that so-called mental work was reduced in effectiveness by continuance and that it had certain bodily effects might still question whether it was really the mental work which was responsible or whether the effects were due to the bodily activities that accompanied mental work. It is true, as is clear from all of the material so far, that mental work always has bodily accompaniments, and all theories would agree that only the physiological processes were subject to fatigue. The opposition reduces to one between muscle and the central nervous system. Even this opposition is not complete, for all recording of mental results involves muscular work, and a doubter could always insist that reduced capacity was due to the related muscular activity alone. The question whether mere mental work has a physiological activity accompanying it which could reduce capacity is still an open one. There has as yet been no convincing demonstration of reduced metabolic index as a sequence to pure thinking. The CO_2 output is not measurably increased by purely mental work so far as Atwood and Benedict can measure it. But results in industry indicate that the comparatively light physical work of the telephone girl shows almost the same curve as does manual labor. Noise and irritation decrease the output. Indirect evidence indicates that the higher nerve centers do show a decrease in efficiency as a result of activity. It seems that what is generally called mental fatigue has a real existence.

Fatigue in Industry. — The industrial applications of results on the nature of fatigue and the curve of output from work are highly important in industry. A knowledge of the suitable length of day, of the distribution of rest periods, and of holidays is necessary if a maximum of output is to be obtained and the health of the workers maintained. Much careful investigation was devoted to the problem during the World War, especially in Great Britain. At that time only efficiency was considered and humanitarian considerations dropped into the background. For efficiency alone it was found that a shorter day within limits gave a larger output than a longer one. Starting with twelve hours, it was found efficient to reduce the hours to eight a day to obtain the maximum result. It also proved desirable to have a regular weekly day of rest. The heavier the work, the shorter the day that could be worked to advantage. What the limit of reduction is that is desirable has not yet been determined. How short a day will permit full efficiency is still an open question. Much depends upon the spirit of the workers. Every one works at a rate below maximum capacity. Special incentives were shown to increase markedly the output of typesetters who had been working years. The low rate of output is in part a natural protective device to prevent overfatigue. In part it is the result of habit and convention. Developing a rapid rhythm for a period by special practice increases markedly the rate of work for the periods following the training. Practice at a rate much slower than the average showed an after-effect of reduced output. The shorter day in a personnel of low morale might merely reduce the output in proportion. In a group of high morale it would increase the efficiency more than enough to compensate for the shorter hours. Many observations indicate that workers adapt themselves to a rate of work not far from the most favorable, that which gives the best results without undue fatigue.

General Rules for Effective Work. — Meanwhile certain general rules can be given which are helpful in the arrangement of work. One must not expect to avoid fatigue. Fatigue as a group of sensations from the muscles or a feeling of lassitude from long mental work is an inevitable accompaniment of all activity. Only when it becomes excessive is it even a signal to stop. As a tendency to an exhaustion of the tissues even, it is still not injurious, for the deficiency is quickly restored by rest, and use is essential to growth, or even to health. All that one can ask is that fatigue should be kept within the limits that permit of quick recovery during the same day if possible, and will certainly give complete restoration after a night of rest. How long this shall be for the individual must be determined empirically. Usually the effective working period is well within the limits that are demanded by health. Probably within this time the limits are set by the sensation of discomfort, or by boredom, or by the conventions of the hours that shall be devoted to work. In practice few students overwork, and those who do are the weaker ones. For industry, the hours are set by the length of day most profitable to the employer. This, when all the facts are understood, will be found well within the physiologically determined limits of capacity.

The Economical Periods of Work. — The most economical period of work is that in which one obtains all the advantages of continued work without going on to the point of fatigue. It is of course impossible to give any general rules that will apply to all kinds of work and to all people. How much work may be done depends upon the nature of the work and upon the strength of the individual. The fact that one does more after working for a little time than when one first begins holds universally. How long one should continue after the effects of fatigue are greater than the benefits of practice, depends upon the kind of work and the practical necessities for its completion. Fatigue itself is not to be avoided, for the lesser degrees wear off in a short time and are entirely overcome by a night's sleep. The poor work that results when fatigue is too great makes effort unprofitable, and the after-effects in the form of overwork may have such serious results as to put a premium upon avoiding them at all reasonable cost.

The Best Period for Rest. — To know how long to rest between periods of work is as important as to know when to stop. Results of experiments indicate that the length of the rest that should be introduced between the periods of work depends upon the length of the previous work and upon the character of the work. The rest should be long enough to permit recovery from fatigue, but not so long as to lose the mental momentum. After long periods of work, two hours or more, the most advantageous intermission is approximately fifteen minutes; for relatively short periods five minutes has proved itself most satisfactory. Longer periods waste too much time, and cause a loss of inertia and of practice that is not compensated for by recovery from fatigue. Shorter intermissions merely cause loss of inertia without any compensating rest. In severe physical work in industry, it has been found as important to insist upon proper and sufficient periods of rest as upon sufficient periods of work. In Taylor's first experiment in efficiency management, which consisted in a study of the best methods of lifting heavy pigs of iron, it was found that if the men followed their natural bent, working with the prospect of a bonus, they would work too continuously, and it was necessary to prescribe rest periods which should be rigidly observed, if the most work was to be accomplished in a day. Mental work requires similar rest periods for the maximum performance, but the best periods for the different types and degrees of work have not been determined accurately. Graf found that the best point to introduce a rest period was after the first two thirds of the working time. Five minutes gave the best results in a two-hour stretch.

Change of Work No Rest. — Several facts that have been suggested by experiments are contrary to the common assumptions of many people. For example, it is believed usually that one may rest through change of work — that if one has been tired by mental work of one sort it is not necessary to rest altogether, but by turning to something else one may become rested through the change. The one important investigation on this point indicates that the everyday assumption is not in harmony with the facts. An hour's work learning nonsense syllables, followed by a half hour's practice on mental arithmetic, with a return to the nonsense syllables, rests one no more than a continued period of nonsense syllables. This is on the assumption that learning nonsense syllables is no more difficult than mental arithmetic. If one turns from a more difficult to an easier task, one will of course not be so tired as if one had continued with the more difficult. So far as these results can be accepted, it seems that all sorts of mental fatigue are of the same kind, and that it is not possible to rest one function while exercising another. There is so much in common between the different mental operations that all become tired together. It is possible that the commonly accepted opinion to the contrary is due to the greater interest one may have in a new task. One ordinarily turns from a task only when obstacles have presented themselves or when for some reason the work has become uninteresting. It is possible that the greater interest in the new work and consequent greater effectiveness are mistaken for recovery from fatigue.

Mental and Physical Fatigue One. — Very similar is the attitude toward the problem of the relation between mental and physical fatigue. It is generally believed that one may rest from mental work while exercising, but experiments indicate that capacity for mental work is decreased by physical work, if it is too difficult. If one takes a vigorous run or other severe exercise between two periods of the same sort of work, as in the experiments on adding mentioned above, the capacity for mental work is diminished rather than increased. Here as before the effect will depend upon the severity of the task. If the exercise be mild, one will rest relatively, just as one does during less difficult mental work. In fact, the whole question of work and fatigue is relative, as one never rests absolutely except during sleep, and even then there is merely gain of repair over waste, not absolute quiescence of all functions. The identity of mental and physical fatigue has been demonstrated many times, both that mental work induces physical fatigue and that physical work induces mental fatigue. One cannot do severe mental work effectively after a hard day of physical labor, and experiments show that one is less capable of physical labor after hard mental work. This general identity of mental and physical work and fatigue is being recognized by the physician. A patient suffering from overwork as a result of too much study or worry is no longer advised to take much exercise, but is put to bed or given very little easy exercise. Of course this does not imply that exercise is not beneficial in health. Exercise is essential to the development and health of the body, and needs no justification. One should not expect to be able to work immediately after exercise, but in the long run the effects of exercise are beneficial.

Morning and Evening Workers. — Another interesting result of recent investigations is that there are daily rhythms of capacity for work, that every one has a certain part of the day during which he has greater capacity. According to one authority, men divide naturally into morning and evening workers. The one group are at their best early in the morning, the other group do not reach their full capacity until toward evening, — the amount and accuracy of their work increases steadily through the day. It has not been determined whether the difference is innate or the result of habit; but in an adult accustomed to mental work, one habit or the other is always readily demonstrated, even if the individual himself is unaware of it. Evidently one should take advantage of the daily rhythm by devoting the best part of the day to the more difficult tasks. There are also minor ups and downs in capacity during the day which may be confused with rest and fatigue in experiments.

General Remarks on Work. — It should be added that the measurements of fatigue upon which these statements rest are derived from ordinary routine work under no particular incentive other than to do one's best. It is certain that a sufficiently strong desire would at any stage have brought the rate of work back to the maximum, at least for a little time. While the amount of work that will be accomplished depends very largely upon the incentive, it does not follow that fatigue is not real and a factor to be considered in the arrangement of the day's routine. The results that have been given hold for the course of ordinary work where the incentive is constant and not particularly strong. If the incentive is increased, the absolute times given would all be increased, but the relative values would still remain approximately the same. There would still come a time when the amount and accuracy of the work would be reduced to a point where work did not pay. Work done willingly and cheerfully under suitable incentives is apparently less fatiguing in the long run than a smaller amount accomplished under unfavorable conditions. One may even agree with James that in moments of exaltation one may perform at a rate far above the ordinary level without permanent injury, and at the same time accept the results of experiments under ordinary conditions as a guide for daily life.

SLEEP

Related to fatigue as its most nearly complete antidote is sleep. One may recover capacity in part by merely resting, but full recovery comes only during sleep. This phenomenon alone would make sleep important for the psychologist as well as for the physiologist. Sleep has a special interest for the psychologist in the fact that it is a period of lack of consciousness, and from the conscious side because of the dream processes. The unconsciousness of sleep is not like the unconsciousness of many abnormal mental states, for one retains after sleep an orientation as to where one was when sleep came on and an approximate idea of the time which elapses during sleep. There is a regular gradation from almost complete lack of awareness, through various degrees of vagueness, to full consciousness. A lack of consistency and logic in the ideas and in the conclusions reached accompanies the reduced consciousness. These are most pronounced in the dreams and gradually decrease with waking. Sleep is not, so far as we can tell, a condition of complete lack of awareness, or of complete immobility. The ideas are few and bizarre and the movements are slight and irregular. Both are forgotten on waking, with rare exceptions.

The Course of Sleep. — The first investigations of sleep were made to determine the period of deepest sleep. The early workers used what might be called the breaking point method. They determined the stimulus, sound or an electric current, that would just suffice to waken an individual at different intervals after the beginning of sleep. While the technique of none of these workers is above reproach, they agree that the period of deepest sleep comes comparatively early. It reaches a maximum within from a half-hour to an hour and a half after going to sleep. In some subjects there is a second maximum shortly before waking. The general fact of deep sleep early and a gradual return to wakefulness harmonizes with results obtained by records of the movements during

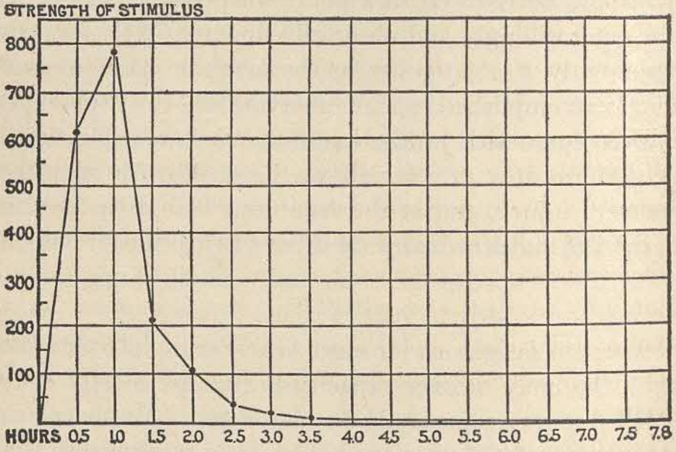

FIG. 117. — Curve showing the depth of sleep at different periods after going to sleep. The figures on the horizontal line show the time since going to sleep; those on the vertical line the relative heights balls must be dropped to waken the sleeper. (From Howell's "Physiology," after Kohlschütter.)

sleep, and with changes in circulation and respiration and with chemical changes.

Movements during Sleep. — Szymansky and Johnson have made elaborate records of the number and extent of movements during sleep, by means of automatic recording devices attached to the bed. Both found that movements persisted all during the sleep period. The average length of time that an individual would lie without a movement varied from 7.3 minutes for the most restless to 21.5 minutes for the least restless. The most healthy individuals had rather more movements than those who were mentally or physically abnormal. Sleeping like a log is not the best criterion for the character of sleep. Patients while suffering from influenza and tuberculosis were more quiet sleepers than when they recovered. The periods of least frequent movement corresponded roughly to the periods of deepest sleep as measured by the stimulus required to arouse the sleeper. The curves were not so consistent as the earlier experiments indicated. There were also marked indications of fairly regular rhythms of greater and less movement.

Theories of Sleep. — The explanations of sleep have been extremely varied. They fall into two general classes. One group makes sleep an active, the other a passive, process. The first assumes that you sleep when there is nothing to keep you awake, the other that you are awake when there is no occasion for going to sleep. Each of these again has a physiological, a chemical, and a psychological form. One of the first physiological suggestions was that sleep resulted whenever the circulation of blood in the brain was diminished below a minimum point. This suggestion was made first by Mosso. Later work, especially by Shepard, indicates that the volume of the brain is greater rather than less in sleep than during waking. This automatically eliminates cerebral anemia as an explanation. The assumption was that the sleeping condition developed because there was not enough circulation in the brain to permit it to continue its function. There are circulatory changes in the brain that enter as sleep comes on. The blood vessels are much relaxed so that the pulse is more pronounced and the increase and decrease of blood in the vessels with inspiration and expiration become more pronounced. These are probably results of sleep rather than its cause.

Chemical Theories of Sleep. — The chemical theory is that the products of fatigue accumulate in the central cortical cells and reduce or destroy temporarily their capacity for action. Piéron has results which lead him to believe that a toxin is developed in the blood by loss of sleep which is different from that developed by fatigue. When blood from an animal that has been kept awake for a long period is injected into the fourth ventricle of the brain of another animal of the same species, it shows all of the signs of sleepiness of the animal from which the fluid is taken. Fatigue products from the muscles do not show the same effect. Piéron's belief is that the toxin of sleep is developed by the action of the cells of the cortex, and might constitute a specific result of mental work for which we were seeking in an earlier section.

The Nervous Theories of Sleep. — The passive nervous theory of sleep was stated often in the early stages of the neurone theory. It assumed that from an unnamed cause the dendrites of the synapses were drawn in and the connections across all the synapses were broken. This left two factors unexplained. One was why the dendrites should be drawn back, the second was how the individual could be awakened. Only a spontaneous putting out of the synapses would permit communication with the external senses. The only justification for the theory originally was an observation that an animal killed by an anæsthetic showed much shorter dendrites than one killed by more violent means.

An active nervous theory is of more recent development.

This was suggested by numerous experiments which have shown that stimulation of the region in the mid-brain about the Aqueduct of Sylvius produces sleep. Hess, Von Hoff, Kauders, and others have reported that injection of the sleep-inducing barbital compounds into the anterior mid-brain region are much more effective than giving them by the mouth. Instances are also reported in which tumors in the lower mid-brain region produce long attacks of sleep. The theory asserts that sleep is the result of a positive stimulus applied to this restricted region. The impulses spread from this region to the cortex in general and inhibit its activities and so reduce the general sensory and motor functions. The theory lacks a definite explanation as to how in normal life this center is stimulated and why its stimulation produces the widespread effects it does.

Sleep an Instinct. — A general theory which makes sleep a positive reaction has been presented by Claparède. Claparède asserts that sleep is an instinctive reaction to definite sets of stimuli. Several analogies may be developed which are in line with this assumption. The first is the long hibernation or winter sleep of many animals. This seems to be altogether or largely a response to the season, or to temperature and other changes that come with the seasons. Another response of quiescence to a positive stimulus is the death-feigning instinct of many feeble animals, such as the opossum, and the young of the terns. To a strong stimulus, they respond by loss of the capacity for movement, which sometimes is accompanied by loss of muscular tonus. Claparède some years ago and Rivers recently have suggested in slightly different forms that sleep is a response of a similar character, which serves to make possible the recuperation of the individual. During sleep cessation of all activity, and increased circulation in the cortex, and possibly in other important organs, stop use and supply materials for rebuilding tissues.

To say that sleep is an instinct does not explain it until we can discover what the nature of the reaction may be and what causes it. The stimulus for sleep varies much under different conditions. In most cases it is a response that recurs at approximately the same time of day. In this animals differ widely. Some instinctively respond by sleep to the coming of darkness, others to the coming of day. The difference is altogether instinctive. In man the instinct is subordinated to habit, and the time of approach of the response and the length of sleep vary with the earlier life and occupation of the individual. In addition the immediate stimulus may be the presence of feelings of fatigue, but on the other hand too much fatigue may prevent sleep. Monotonous stimuli are also frequently followed by sleep. Absence of stimulation acts as a monotonous stimulus. All stimuli for sleep work best when accompanied by suggestion. If one expects to sleep, sleep is almost certain, unless other circumstances are unfavorable. Excessive fatigue will also finally result in sleep, but can be fought off voluntarily, or under the influence of strong stimuli, for a long time. Animals kept awake by strong stimuli will die after a few days. Loss of sleep is more quickly fatal than is starvation. Fatigue seems to be an inducing condition, and sleep is more and more likely as fatigue advances, provided other conditions are favorable. It seems to be a contributing condition rather than the immediate cause, until it becomes very intense. The final collapse from exhaustion seems to be not quite the same as the normal sleep in moderate degrees of fatigue. It is more like an intoxication.

The observed phenomena of sleep seem to combine most if not all of the factors that have been suggested as the causes of sleep. Measurements of the course of sleep show that there is a constant increase in the depth of sleep as indicated by the strength of the stimulus required to waken the sleeper, and by the number of movements during the first hour and a half.

After that there is a diminution up to the time of waking. Accompanying this there is a decrease in blood pressure during the first part and a rise in the latter part. On the nervous side, the reduced stimulability has been interpreted as due to an inhibition of the cortical centers; it has also been regarded as a mark of dissociation, for certain of the phenomena of sleep-walking and dreams seem allied to hypnotism and similar processes, that are explained as due to dissociation. One may think of sleep, then, as a reaction in which the central nervous system has its activity inhibited, and the action of the lower centers checked, which carries with it changes in circulation and respiration and prevents the activity of muscles and glands. The net result is a state in which recuperation is possible. It is also a self-terminating process. As the tissues are restored, and toxins removed from the tissues and from the circulation, the susceptibility of the central nervous system is restored, and any stimulus is more likely to induce the activity of the cortex which brings with it the release of inhibition and restoration of the functions of circulation and respiration.

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CHAPTER XXI

PERSONALITY AND THE SELF

VERY important for the individual interest and for dealing with people are the questions of the nature of the man as a whole rather than or in addition to the various special aspects that we have been discussing. The general tendencies to response of an individual as appreciated by others we know as his personality. If he is likely to be suspicious of motives, is aggressive, has qualities of leadership or has the opposite of each of these qualities, we need to take it into consideration if we are choosing him for employment or even as a friend. Personality is of course primarily a popular term, and as such it has many diverse meanings. Taken together the qualities which we group under the term *personality* constitute most of the factors which determine the probable success and happiness of the individual, and the satisfaction of the people who come into contact with him. So important are the qualities that a psychologist speaking popularly is quoted by the papers as saying that 15 per cent of the success of the individual depends upon his intelligence, the rest upon his personality. Statements such as this are beyond the range of proof, but may indicate the importance of this aspect of man in the eyes of the public.

Use and Abuse of Term Personality. — The very importance of the qualities grouped under it has led to much nonsense being spoken and written about personality. Men with little knowledge of anything give public lectures and private lessons on how to develop personality. If the speaker is plausible and the audience gullible, an interesting hour is passed, and occasionally encouragement is given to the listener. More time must be taken lauding the importance of personality than in specific directions how to acquire it. The term personality is so vague in its use that a definition is hardly possible. We can reverse the statement of our newspaper psychologist and assert that personality is everything about a man other than his intelligence that influences his success. Personality is a compound of emotional characteristics, of capacities for action, and of what is popularly called tact, or the sum of capacities for social and personal judgments and responses. Its very generality limits the usefulness of the term. Attempts at classification of different kinds of personality in this popular sense can hardly be expected to succeed and none have succeeded. The roots of personality are found in the entire native reaction tendency and acquired habits of the individual. Specific directions for developing them are obviously impossible to give in detail.

Classifications of Personality. — Aside from such ratings of individual differences as were mentioned on page 227, three of the most recent attempts to divide individuals into different groups may be discussed. Two of these are based upon differences which are important in mental pathology and one grew from experiments. The two that developed from pathology tend to merge into each other. One author would divide all individuals into introverts and extraverts. The one group tends to turn in upon themselves; the other is more interested in others and in objects. The second classification assumes that normal individuals tend to follow the line of demarcation that is shown by the symptoms of the two most common forms of mental derangement, the circular insanity and schizophrenia. It asserts that all individuals show in some slight degree the differences that are highly developed in the serious disturbances of the insane. The upholders of this view call those that resemble the circular insanity cases in mild degree, the cyclothymes, while those who resemble schizophrenic patients are the schizothymes. We may consider first the introvert-extravert distinction.

Introversion and Extraversion. The Introvert. — This distinction of introvert and extravert was first suggested by Jung to explain certain differences between individuals that had an important influence on their action in mental disease and in their normal responses to the world. Members of the one group are unusually interested in their own reactions and inner thought processes, to the extent of being unwilling to meet other men. They become unwilling to talk even about themselves. They seem cold and without emotions to those with whom they come into contact. This is only seeming, for they are really constantly throbbing with emotion. The emotional life is merely not permitted to show itself. Introverts are extremely sensitive to their own standing and are anxious to assert their own position. Keen for praise, they give no indication of having any interest in what others think even of themselves. They blush easily and are readily confused. They avoid prominent places in crowds and cannot readily be induced to address groups.

The Extravert. — The extravert shows the opposite tendency in each respect. Extraverts are interested in the world and in other people. They rejoice in manipulating others. Extraverts are said to be good salesmen and executives of all kinds. On the other hand they are open to suggestion from others and from objects. They are readily led and live to adapt themselves to the external realities of life. The extravert lacks marked opinions of his own. He is not sensitive to the opinions others may have of himself, but he does yield to their desires. He leads in the direction prescribed by others. He expresses himself well, and is very free in showing his emotional reactions. On the whole the extravert passes for a happier individual than the introvert. He is at least not given to hiding his joy any more than he hides his sorrow. When he is happy, it is known to all who come in contact with him. When sad, his sadness is equally manifest. Extremes of mood rather than the neutral attitude characterize him.

Measurements of Introversion and Extraversion. — After Jung made his general suggestion that men could be divided into introverts and extraverts, Freyd devised a series of questions for the purpose of making a more definite division of individuals into the two classes. He first drew up a set of fifty questions which if answered positively would indicate one and if answered negatively would indicate the other type. He applied the test to members of different callings that were assumed to demand one or the other of the characteristics preeminently. He attempted to confirm the results of the tests by ratings of friends. He was fairly well satisfied with the agreements. Others have shortened the list of questions by eliminating those which proved to be less diagnostic, until a series of thirty was retained which seemed fairly satisfactory.

The great drawback in the interpretation of the tests is that we have no groups of individuals who are known to be either introverts or extraverts and who might constitute a standard group to validate the tests. Two attempts have been made to justify the value of the questions themselves by giving them to insane patients who have been diagnosed as belonging in the group of circular insanity and schizophrenia respectively. The results indicated that the individuals who suffer from circular insanity are predominantly extraverts, while those who suffer from schizophrenia are predominantly introverts. In one experiment there was complete agreement between the diagnosis and the answers given to the questionnaire. In the other some deviations were noted but there was a general agreement. The correspondence between schizophrenia and introversion was suggested by Jung. He also asserted that extraverts were likely to be hysterical but he had not related the condition to circular insanity. The effect of this relation between introversion-extraversion and the types of insanity gives the beginning of an objective standard, and is important in connection with the division into cyclothymes and schizothymes, which we shall next consider.

Types of Insanity and Body Types. — Kretschmer was led to the classification of normal individuals on the basis of the insanity types indirectly from observing that there was a characteristic difference in body form between the circular insanity types and the schizophrenic group. He noted that most of the patients in the first group are of what he called the pyknic type. They are always well padded with fat, the shoulders are relatively small and the hips large. The heads are round, what is known as the brachycephalic type, — that is, the cross diameter is relatively long as compared with the sagittal diameter. On the other hand patients suffering from schizophrenia fall either into the athletic or into the asthenic types. Both are alike in having heads of the dolicocephalic type, that is, the sagittal axis is relatively long as compared with the cross axis. They are alike also in having little flesh. The asthenic has poorly developed muscles, and shoulders and hips are both small. The athletic type has well developed muscles and broad shoulders, but narrow hips. More than 90 per cent of the circular insanity cases fall into the pyknic class of body build, and a similarly large percentage of the schizophrenic group are either athletic or asthenic in build.

Types of Insanity. — To appreciate the importance of this division and of the application of the distinction to the general population a brief sketch of the symptoms of the two forms of insanity must be given. The cases of circular insanity show a successive alternation in emotional reaction, and in bodily and mental activity between opposite extremes. Hence the name circular insanity. The patient may show first what is known as the manic phase. In this the patient is usually happy and optimistic as to the future, is easily excited, is constantly moving, and shows a great flight of ideas. He passes rapidly from one idea to another with little logical connection between the parts of a discourse. This phase or attack usually lasts a comparatively short time, a few weeks or months. After some years, there is likelihood that a second attack will come, in which the patient shows just the opposite set of symptoms. He is very much depressed emotionally, has a great impulse to commit suicide, moves as little as possible, may lie quiet in bed for days, and shows a very slow flow of ideas. These two states may alternate in appearing at gradually diminishing intervals during the remainder of the life of the patient. During both forms of attack the patient is not to be trusted in his judgments of complicated affairs nor to control his acts toward others and himself. In the intervals between attacks he shows little deterioration and is fully competent to manage his affairs.

The Schizophrenic Type. — The schizophrenic patient, previous to 1910 called a dementia precox patient, shows no rhythm of recovery and attack. It is a disease that appears relatively early in life, mostly between fifteen and thirty-five, and usually continues during the life of the patient. The patient seldom recovers, and when he does, shows a marked mental deterioration after the active symptoms disappear. The disease takes different forms, but all are alike in showing the deterioration. The symptom complex is nearly always marked by delusions that are only slightly developed. By delusion is meant a belief that is not only false but opposed to the data that the patient has at his disposal. He may believe that he is being persecuted for no fault of his own, or he may believe that he is possessed of great wealth, or is an emperor, or is the son of a wealthy man who has been kidnapped and reared by his seeming parents. These delusions are usually not completely consistent and may change from time to time. The emotions are completely repressed. The patient maintains an expressionless countenance and speaks without indicating either pleasure or pain. He seems to be living apart from all interest in the world. Occasional revelations indicate that he really feels more than he permits himself to admit. He shows that he really has an emotional life so strong that he cannot bring himself to face it and so suppresses it. This phenomenon it was that led Bleuler to apply the term schizophrenia, which means splitting of control. The phase that is shown seems emotionally crippled, but the deeper phase has all the affective life of a normal individual.

Cyclothyme and Schizothyme. — On the basis of his observations of normal individuals and studies of men of distinction, Kretschmer formed the opinion that all men show in slight degree the characteristics of one or the other of these symptom groups of the insane. The one group is marked by interests in the outer world and other men, by a quickness of understanding, rapid change in emotional attitude, which is freely expressed, and marked readiness for action. This group usually contains individuals of the pyknic bodily type. They are the men of action in the stronger types, the men of affairs and the experimental scientists. These Kretschmer calls the cyclothymes. Opposed to these are the group of individuals who are self-conscious, timid when with others, always reticent in the expression of their emotions, except when there is an explosion. It is the reserved, cold, aristocratic type. In life they are likely to be the philosophers and meet the problems of life in theory rather than in action. When they act it is with deliberation and a complete knowledge of the facts. The schizothymes belong in bodily type in the athletic or asthenic group. Many different variations in each of these classes are to be recognized. In part the variations are in the closeness of approximation to the abnormal; in part they are shown in the strength of different minor characteristics. There are cyclothymes who are weak seekers after pleasure, with no definite goal in life, and there are also cyclothymes who press relentlessly towards a definite end. Similarly there are schizothymes who spend their lives in dreaming of possible accomplishments that are never attempted. Others formulate their ideals clearly and press on to their realization. We have time to consider only the main distinction. It will be noticed that the cyclothyme and schizothyme differences closely parallel those between the extravert and introvert. While the formulation of the two divisions developed along different lines, the types represented fall into the same general class. The similarity is emphasized by the fact that schizophrenic patients are introverts and the circular insanity patients are mainly extraverts.

The Eidetic Types of Personality. — Of less general application is a suggestion of Jaensch that one may distinguish certain types in children on the basis of the clearness of the visual memories. As will be remembered from Chapter XI, Jaensch discovered that children in general have much more definite visual memories than adults and that in quite a large number of children the memory images are projected on the background and can scarcely be distinguished from real objects. In the group of eidetics, Jaensch found two distinct classes. In one the eidetic images are fixed and rigid. They cannot be changed at will and do not change voluntarily. They do not change color, they do not depend for their intensity upon interest at the moment or at the time the original object was seen. They act very much like real objects. In the second class the images are more variable. They shift with the attention and behave in general very much like memory images. They vary with the interest of the moment and can be controlled within wide limits. Jaensch was able to correlate these differences with the activity of the thyroid glands. The fixed eidetic images are present in children who have a deficient thyroid secretion. This he called the T-type because children who belong to it occasionally show signs of tetany. The other type with controllable and varying eidetic imagery he related to the oversecretion of the thyroid. He called this the B-type, because it shows similarities in physical characteristics to Basedow's disease. This division is of interest in calling attention to the importance of the endocrine glands to personality. Kretschmer, too, ascribed the differences he recognized to the dominance of glands, but could not be so specific in connecting a given gland with a certain type. Jaensch's classification is not one that takes into account a wide range of characteristics.

The three attempts at the classification of personality are mentioned because they are definite, although the basis of classification is relatively narrow in each case. Many other attempts have been made to include a wider range of capacities and types of reaction. All fail from the very attempt to be inclusive. The resulting complexity makes them all fail to give a picture clear cut enough to be kept in mind or to be readily applicable. Much to be desired is a system of classification of personality concise enough to be remembered and flexible enough to be applicable to all individuals. These that have been mentioned are suggestive of what may be done later. They may be supplemented or transformed as new developments come.

The Self

Related to the problem of personality as subjective to objective is the question of the *self*. When we are dealing with the peculiarites of other people and the forces which make them act as they do in important ways we say we are interested in their personality. When we concern ourselves with similar central problems of our own life, we refer them to the *self*. In popular usage, the word 'self' is given a meaning that has been derived from older philosophical and religious notions. It is thought of as a real existence that is much like another person existing somewhere within the individual we know who makes all final decisions, and can be used to explain all problems that are not easily referable to other laws or other principles. This use of the term cannot be justified by observation. A theory of that kind also is not useful in understanding phenomena, since it can give no explanation of details. The word 'self' is useful to indicate certain general responses and definite functions of the individual as a whole. The occasions for the use of the term and the limitations that can be put upon its meaning can be stated briefly. In this sense the self is always a more subjective phase of experience as opposed to a more objective. We can distinguish also different degrees of subjectivity and objectivity in the applications of the word 'self.'

THE VARYING CONCEPTS OF THE SELF

The Physical Self. — The most naïve and obvious of the distinguishable forms of the self is the physical self which opposes the man as a whole to other persons. The center of reference for the physical self is of course the body, partly as it is seen in the field of vision, partly as it is reconstructed on the basis of mirror images and photographs and from the references of friends. The meaning of this physical self is very much wider. It is used to refer to the body, together with many of the man's immediate possessions, — garments and adornments, and an ever-widening group of properties. The 'physical self' gradually comes to be indistinguishable from the 'physically mine.' Houses and lands, friends and position, all of the things that one must struggle with other men to retain, come to form part of the physical 'me.' This physical self derives much of its meaning from comparison with others.

One tends to see one's self in relation to others about. The man's picture of himself and of his possessions always involves a comparison with others and with the ideals that these set for his own attainment. The wealth of the individual, rich and poor alike, has increased enormously in the last century, but nevertheless the line is quite as sharply drawn now as ever before, since the relative differences are approximately the same. Similarly, one's opinion of one's physical self in the narrowest sense varies with the individuals with whom one comes in contact. One feels one's self quite a man among small men, while there is a decided shrinking when with men of large stature. One can imagine how different Gulliver's impression of himself must have been when in Lilliput from what it was among the Brobdingnagians. This first self-concept represents the man to himself as a man among men. It is the self in the most practical, popular sense.

The Subjective Self. — More closely related to the popular theory of the self is the subjective self, which James called the spiritual self. This is the more personal aspect of the mental experiences as such. It designates the conscious processes as opposed to the physical brain states, and among conscious processes is applied to those which are more central. It would probably designate the reasoning and imaginative processes rather than sensations; the more voluntary actions as opposed to habit and reflex; the emotions attaching to higher acts rather than the more specific feelings. The line of division between the subjective self and the not-self is not clearly drawn. The self begins a little more centrally in one connection than in another. It is very much less fixed than was the old picture of a real separate self, although it may be the degenerate derivative of that notion.

The Effective Self. — More important for the explanation of problems and in need of definite formulation is the concept of the effective self. This is a concept that refers to the final deciding activities of the man as a whole. It is convenient to group together the known peculiarities of each man in higher acts both mental and intellectual. These cannot be referred to any specific act or fact. The different general groupings of mental phenomena seem to be dependent one upon another. There are common elements in attention, in action, in reasoning and recall, but no one is definitely more final in its explanation than any of the others. For convenience the psychologist needs to refer to the fact of decision and the forces that determine decision, and to the characteristics that are common in all of these acts. The effective self provides a means of designating these factors.

In each of these more active processes, one feels that there is something that must be explained in terms of factors that cannot be definitely formulated. The tendency is always to bring in some other simple process as the basis of the explanation, hence the reference from one process to another among mental states. But, when one sees that one can complete the circle and come no nearer the explanation in one group than in any other, it is obvious that going around the circle has not furthered the explanation. Two alternatives remain open. One may assume either that some highest process controls all the others, or that there are common elements in each; and then seek to determine what these are. The popular mind takes the first of the alternatives, — assumes the self as a prime determinant, and makes it the final force in all spontaneous action. Since, however, this is in reality no explanation but merely a tagging of the facts that are to be explained, it is more important to determine the elements common to each. This we may find in the developed ideals and purposes, which in turn are to be referred, first to instincts, then to the ideals of society taken over by the individual largely by virtue of the social instinct — the instinct to seek approval — and then tested and confirmed by his own individual experience. If other factors enter, they cannot be traced, either in the introspection of the agent or by a study of the behavior of others. In the complexity of the conditions that act upon the individual we are not, however, in a position to assert that no others are effective at any point.

The Social Factors in the Self-Concept. — These three concepts of the self tend to fuse into a single one in which something of each is retained, and all are more or less harmonized into a unitary whole. The representative self has something of the body, something of the mental as opposed to the bodily, more of the strain processes that mark it as active. The concept is ordinarily employed to distinguish between the self and society, between the 'I' and the 'You,' or, objectively, between the characteristics of the different individuals with whom one comes in contact, who must be used in the accomplishment of one's ends, or who use one in the attainment of theirs. With this there is a marked effect of the life in society. Both the static and the dynamic features of the self are appreciated only in terms of others about. One has an idea of one's own peculiarities only in comparison with others. One's notion of one's self as a whole is largely an image of the self as it is reflected in the consciousness of others. When a man is among men of smaller attainments, or smaller possessions, he expands; when he is with men of larger accomplishments or reputation or possessions, he shrinks just as evidently. Much of this idea of the self depends, not upon actual ability and possession, but upon the imagined attitude of others. A man becomes accustomed to act as if he were of more than ordinary importance, society takes him at face value, and he may go for years or even through life without having the notion corrected either for himself or for others. But a few rebuffs to a sensitive individual will repress his self in his own eyes and prevent any self-assertion. If he has high ability, it may go for years without being discovered. Society makes its judgment of a man in part from his own actions; and these in turn depend in some measure upon the estimate he thinks society puts upon him. The process is a cyclical one. The individual's estimate of himself is what he believes to be society's estimate of him. On the other hand, society's estimate of the man is very largely colored by his estimate of himself and his consequent bearing. The way in which the individual pictures himself and the estimate of his personal capacity are largely derived from the attitude of society toward him, just as many of the forces that control his active life are merely an expression of the society in which he lives.

The Emotions of Self. — The activities and processes that develop the notion of self are very largely emotional. What we called the more complicated emotions, those which come from the interaction of the purposes of the individual with the environment, are largely social in character. The opposition is most often from other men, and the emotion is usually ascribed to an expanding or shrinking of the self. In fact, in much of our daily life, the only reason for making use of the notion of the self is to picture the origin and the immediate source of the emotion. We are concerned with the self only in moments of struggle and in the consequent success or defeat. In periods of quiet contemplation of external objects or even in the unhindered manipulation of things, we are little aware of the self. With opposition, particularly from other men, the complex of emotions comes into play. We have the self-assertion of effort, the elation of victory, the self-depreciation of defeat. That these emotions are always of a social character is seen in the fact that if one performs a difficult feat when alone, there is always a thought of what some one else might think; and the pleasure in the success comes largely from the background of realization that it is better than could have been done by one's rival. The onlooker is always present in thought if not in reality, and the resultant emotion is determined by the way the action would be viewed by him rather than by any absolute standard.

These self-regarding emotions constitute the core of the idea of the self. The character of these emotions seems to depend upon the relation between the ambitions of the individual and his actual accomplishments. James puts it in the statement that self-esteem equals success divided by pretensions. When pretensions are large, success small, self-esteem is slight; as success grows or ambitions diminish, self-esteem or self-complacency is increased. Self-esteem, too, is only affected when success or failure comes in some field in which the ambition of the individual lies. A scholar may very well content himself with little of the worldly goods, may even regard wealth as somewhat vulgar, since he has never set himself towards its attainment. The wealthy man of affairs returns the compliment by saying he can buy the services of a scientist much more cheaply than he can the advice of a financial expert, — that learning is a drug in the market. Each is satisfied with his own position, with his own self, as he has never attempted to extend the self in the field of the other. But when men of affairs come into rivalry in the same field, the self of the one is humiliated as the other attains what he has himself sought.

The emotions toward the self, or the conditions that lie behind them, not merely determine how the individual shall regard himself, but also play a very large part in deciding the degree of effectiveness of the individual. The way in which the self is regarded determines the attitude toward the problems of life, and this in turn is an important factor in the success or failure of the individual. The character of the individual, viewed either from within or from without, is closely related to his self-esteem.

Practical Effects of Emotions of the Self. — The man who has succeeded and lacks a sense of proportion or the saving sense of humor becomes self-conceited. He can no longer remove his mental gaze from contemplation of his own capacities and of past successes, nor can he avoid expressing this appreciation of himself, nor conceal his expectation that others will express their appreciation of that position. A child who is always the center of the approving household develops an exaggerated notion of his own importance, and his early success in business or scholarship not infrequently sets an attitude of self-satisfaction that cannot be disturbed even by later failures and rebuffs.

More striking is the expectation of failure and consequent lowering of ambitions that comes with crushing defeat. A man of middle age who suddenly finds his system of ambitions thwarted and all of the accumulations of previous successes swept away, seems to lose not merely all of his ambitions, all of his self-respect, but also the capacity for forming new purposes. The self disappears or is profoundly altered with the despair that follows. Numerous members of the drifting colonies of ne'er-do-wells of our large cities have been brought to their position by some such catastrophe. The man of means who, at first confident, self-assertive, and persistent, loses his wealth through some mischance, and fails in the first few efforts to reëstablish himself, comes to mistrust himself and all his ventures, — becomes vacillating. Others lose confidence in him, and he either decides that nothing is worth while, takes a carefree attitude toward the world and attempts nothing, or falls into despair and, while his ambitions are retained, gives up hope of realizing them. In brief, the system of ends feeds on success and grows as each ambition is realized, but shrinks and finally disappears with repeated failure. Happy is the man whose ambitions are not too different from his capacities and to whom environment is sufficiently favorable to permit the realization of ambitions in sufficient degree to give constant encouragement, without too great expansion of the notion of his capacity and importance.

The Self as Concept. — We may bring together our conclusions in the statement that the self is a concept or group of concepts originally developed to represent the different lines of division between the man and others, between the mental and physical processes, and between the more mechanical and the more spontaneous forms of action. The different concepts are frequently fused, at least in part, into a single concept which becomes representative of the system of purposes as they control actions, which gives rise to emotions and serves to designate the directing forces in the more complicated mental processes. This concept is the point of reference for all our self-regarding ambitions, it is the self we are depressed about and the self that we exult over. Nevertheless it must not be assumed that something corresponding to this self can be found by introspection. Just as space, regarded as a concept, was needed to explain certain of the ways in which we see objects and the possibilities of movement, so the concept of the self is merely a way we have of representing to ourselves the immediate facts found in the emotional and the active life, in the life of decision. Examination gives us nothing more than does contemplation. We can analyze the way in which we perceive space relations into certain elements, we can show why we need the concept of space, but we do not expect to find anything more by any means. Similarly with the self, we can point to certain strains as usually present when we think 'I,' we can show why it is needed as a means of making certain distinctions, but we should not expect to find anything more by observation or experiment, — and we do not.

APPLICATIONS OF THE SELF-CONCEPT

Self-Identity. — Several problems of a general psychological or philosophical bearing become simpler when use is made of the self-concept. One of the most frequently discussed of these is the problem of how the continuous, ever-changing series of mental processes can all be referred to the same individual and regarded as belonging to a unitary self. As a matter of fact, the practical man is never bothered by this problem. In observation he is concerned only with the things that are meant. It is only in recognition that the fact that he has seen a thing before is important to him, and even then he is more interested in knowing that the object was in a certain place at a certain time than in the fact that he saw it there. The different experiences are held together as parts of a single whole by the interrelations that make recognition possible, that make it possible to refer each experience to a definite position in the series. This fact of reference is immediately observed. When the self-concept has developed, the theorist makes that the point of reference, in spite of the difficulty in seeing how an actual substantial something apart from the experiences could hold them together. If by the self we mean the experiences themselves as interrelated one to the other, the notion offers less difficulty.

The Unity of Consciousness. — That all the mental states form a unity at any moment can be explained in terms of the self-concept. Again it must be insisted that what is or can be noticed is the unity, so far as that exists, rather than an ego. A self in addition to the states would not give them unity. Rather must the unity come from the interconnection of mental states, the subordination of all to some single one that is the central point of attention. As has been seen frequently, many processes, some corresponding only to partially aroused association paths, coöperate in constituting any single experience. In part this unity is explained by the nervous system, in which many neurones are always aroused together and the action of each produces a spread of impulses to all of the others; in part it is to be referred to the interrelation of what might be regarded as single elements in the formation of concepts and meanings, the real mental units. In any case the unity is within the mental states, not a unity that comes from without through a connection with some single thing. In both of these cases, as in the more empirical active and emotional processes, the facts are to be found in the continuity and unity of mental processes; the self-concept is developed or introduced to explain them. It is merely a method of picturing, not an actual experience. Here the concept is even less satisfactory as an explanation than it was in the preceding instances.

In one respect the more cognitive processes which are explained by this more passive type of self may be combined with the more active discussed above. The system of purposes which was seen to be the deciding factor in deliberate action, and in determining the character of the emotions, is closely bound up with the system of knowledge. Given the instinctive basis, each experience modifies that instinct, and gives it definite content, at the same time that it aids in the construction of our system of concepts and prepares the way for recognition and for meaning. In this way the two groups of systems become closely interwoven and are probably for the most part merely different expressions of the same fundamental unity. When active in the control of perception and reason, we term the result the cognitive processes; when acts and emotions are involved, we speak of purposes. All education influences each system, though in different degrees. The system of purposes closely determines the acquisition of knowledge and the use made of it in memory and reasoning; while the knowledge obtained has its effects on the formation of purposes. It is the close interrelation and dynamic interaction of all parts of experience that really give a unitary character to the acts of the individual, determine his intellectual interests, and make possible the continuity of recognition and of meaning.

DISSOCIATIONS OF THE SELF

Dissociations of Personality. — That this interrelation of all parts probably has a physical basis is evident from the fact that in certain abnormal individuals the unity of memory or knowledge and of purposes may be broken up into two or several systems, each of which acts alone to produce all the capacities of a whole individual, but which differ in the characteristics of each of the partial personalities. The cases of alternating or dissociated personality offer much of dramatic interest, which cannot be treated here. A person who may be in fair health will suddenly find himself in a strange situation, with no memory of anything that has happened before. In one case even the most rudimentary knowledge of simple things was lost, and some days were required for the patient to recognize simple objects, and still longer to learn to speak. For a long time this second set of experiences remained cut off from the old, then finally the patient awoke again with no memory for recent events, as if he had just waked up into the first set of experiences. In most cases the second self comes into being with a portion of the original memories and experiences of the old. There is a dissociation of the old into two or more parts, rather than a development of an entirely new series. The patient suddenly wakes in an unfamiliar environment, with no memories of where he may be or of recent events, but with full command of language and the ability to interpret the objects about. After that the different personalities or groups of experiences alternate. The time occupied by one self varies greatly, as does the occasion for the change from one to another.

Characteristics of the Partial Selves. — If we relate the characteristics in which the selves vary, and the marks that distinguish them one from the other, to the facts that have led to the development of the self-concept, we find that practically all of them may be closely paralleled. One element in the consciousness of self is the persistence of various organic sensations. One feels at home in the body, if we may indulge in metaphor, because the strain sensations are constant from one time to another. Ribot reports some cases of split personality in which the organic sensations were changed, and suggests that the change might in part have accounted for the alteration of personality. Much more important is the break in the line of association, the inability to recall an event in one state which has occurred in another. The train of memories seems to be broken off sharply when the personality alternates. Everything that happened in one state can be recalled in that state, but all the experiences of the other state are lost. There is, furthermore, no recognition in one state of the objects seen in another. The associations that connected them originally are completely broken, while the associations within each group persist. It is this characteristic that gives the name of dissociated personality. In the dissociation there seem to be peculiar divisions of the original self. In the Beauchamp case, reported by Dr. Prince, one self kept the knowledge of French of the original, while the others were entirely without it; and other acquirements seemed to be assigned to one alone of the personalities.

Not merely are the acquirements differently divided, but the active and emotional characteristics seem also to vary. One self will be highly conventional in action and desires, will respond very quickly to social controls; the other will be entirely arbitrary in action. The difference may approach that so vividly pictured by Stevenson in his story of Dr. Jekyll and Mr. Hyde. The purposes of the two selves are different, as are also the memories. This is in accordance with our explanation of the development of ideals by the action of the accumulated experiences. When the systems of knowledge divide, the control exerted by each of the two sets of ideals or purposes is exerted differently according to the components that make it up. Dr. Prince suggests that in certain cases the instincts as well seem to be divided. One self will take most of the tender and benevolent instincts, the other most of the aggressive, the rebellious, anti-social instincts. Where one self will be painfully conscientious and considerate of others, the second will be altogether selfish and indifferent to the ordinary family and social welfare. With the break in knowledge, there goes a corresponding sudden alteration in the effective self. The individual shows different emotions, is differently controlled in action and in thought. Aside from the fact that both selves are still in the same body, they are essentially two individuals, two selves. There is no memory or recognition of events that occur to the other self, there is no consistency of action between them, there is no continuous self-consciousness from one to the other. Both the theoretical and practical characteristics of the two selves are altered.

The Phenomenon of Dissociation. — If we attempt an explanation from the physical side, it would seem that the various effects upon the nervous system are retained and organized into systems; that these systems, while ordinarily acting as units, may by certain shocks be dissociated along somewhat definite lines of cleavage which also develop as a result of the formation of distinct systems. When the break comes, we have each system or group of systems persisting, but with no bonds of connection between them. Each system continues to act alone, and to control the responses through the persistent nervous connections, guided by the wider series of partially active neurones. In most cases certain of the more frequent nervous activities are common to the two systems, but this shows itself only in the persistence of the nervous correlates of more general concepts and ideas, to which each of the new experiences may be referred to be understood, with none of the more specific references that constitute recognition. The normal self has as its correlate on the physical side a complete system or system of systems, from all of the more important parts of which impulses may pass to awaken all of the other parts, — a system that embraces and unifies many lesser systems, all of which are connected. So long as this system remains unbroken, memory is continuous, memories from all parts of the life may be recognized, and the actions are sufficiently controlled to be consistent. That this is the basis for the characteristics that we have regarded as constituting the peculiar condition of the self is evident from the fact that, when this complete system is broken into two or more groups of systems, two or more selves make their appearance.

Hypnotism and Other Forms of Dissociation. — Not only does dissociation arise spontaneously, but in many individuals it may be induced at will. If, for example, a patient be asked to keep attention continuously fixed upon some one object, he will pass into a cataleptic stage, his muscles will stiffen, and he will gradually to all appearances become unconscious, and in the higher degrees of the resulting abnormal condition will show many of the phases of the dissociated personality. The state is much more readily induced if the patient remains passive and is told from time to time that he is going to sleep. When most completely hypnotized, the patient is highly suggestible, will do anything that he is told to do, may even be made to take on different personalities. On waking there is ordinarily no memory of what has happened during the hypnotic state, although when hypnotized again, the person may recall the events of this period. The close relation between this and the phenomena of the dissociated self is indicated by the fact that change from one self to the other often can be induced by suggestion in the hypnotized state and that when hypnotized in one state, that self will recall events experienced in other states. In many diseased conditions there is evidence that partial dissociation of these systems may take place and may be responsible for the disease. Hysteria is largely, if not altogether, due to a breaking away from the whole of some one of the systems. The system broken off may not be large enough seriously to disturb the higher coördinations of the self, but the break does prevent the dominant system from receiving impressions from certain sense organs connected with the dissociated elements, and may also cause a paralysis of the muscles that are either permanently or temporarily united with those dissociated elements.

THE SELF AS THE WHOLE MAN ACTIVE

Consciousness and Subconsciousness. — Numerous theories have suggested that the self is seldom completely united, that there are always larger or smaller groups of experiences or memories which are independent of the larger system. Thus, Freud, as we have seen, explains dreams and many of the accidents of daily life as well as the witty sayings of the normal individual by the fact that he has an organized complex of elements, which usually contributes little to consciousness but which on occasion will be excited and when aroused opens new possibilities for good or evil in the individual. This detached complex is frequently said to have all of the elements of the normal or total self, to have desires of its own, to do thinking for itself, — in fact, to constitute a true self, which is also regarded as having a kind of consciousness. Many facts point to the presence of these complexes, and the assertion that a definite consciousness attaches to them raises many questions as to what our ordinary consciousness may be, and upon what it depends. It must be granted that these subconscious systems have many, if not all, of the characteristics of the complete system. We could personify them as readily as we do the experience of many other individuals. The only test of consciousness from the inside, however, is the personal test —

that we are aware of it in introspection — and by definition this subconscious does not fulfill that condition.

However, so many of the determinants of our personal consciousness are not themselves directly conscious that the difference may not be important. Of all of the myriad activities in the nervous system, only a few can be known at any moment; and, as has become apparent from the study of meaning and related processes, no one of these is conscious, of and for itself alone. It must always be grouped with a number of other activities, if consciousness is to result. Even then consciousness is limited, in most cases, to the things referred to or meant, rather than to the elements that are supposed to carry the meaning. Each group of nervous elements may by its activity contribute to the consciousness of the total, but the conditions of consciousness must still be regarded as obscure. The most that can be said is that, of the different systems which are found within the nervous system at any one time, the largest and most active is accompanied by consciousness. The others are either completely suppressed, as in the case of the complexes of the subconscious or unconscious, or the minor systems contribute only in some slight degree to the total consciousness. Consciousness seems to be determined by or to accompany the activity of a system of nervous elements, connected by virtue of acting together in various systems of experiences. How many elements may be included in what corresponds to the center of consciousness, and how far less central elements contribute to the whole, no one can say. It can be asserted with assurance that even the most central features of consciousness correspond to the action of many neurones, show the effect of many experiences, and represent even more. Where the limits are to be drawn is not to be confidently stated.

The Self and the Individual. — Very little of the nervous action is really accompanied by consciousness, although a very large part of that activity has an effect upon consciousness. Much the same statement may be made of the functions of the individual, as we deal with him in psychology and everyday life. We know that he remembers and recognizes, that he perceives objects, and reaches conclusions, that he feels and chooses; we can even trace many of the conditions of these different operations, but he himself is conscious of little more than the outcome, — the causes are not revealed in consciousness.

A close analysis of self-consciousness gives as little reward. One has certain concepts which are represented by more or less definite imagery, but again the important factor is not the imagery but what the imagery represents. This is our notion of the whole as active, of the processes that direct our thoughts and acts. It constitutes a continuous experience, with the possibility of referring from any part to any other. All these are involved in the self idea, but are not all conscious at any time. The consciousness of self is seldom present and is of little importance when present. The self as the whole man active, as the unity and continuity of experience, is fundamental. We must again emphasize that the self is not a single experience among the other experiences. It is not something of which we may become immediately conscious. On the contrary the self is the man with all of his experiences and activities viewed as a whole.

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CHAPTER XXII

CHARACTERISTIC SCHOOLS OF PSYCHOLOGY

IMPORTANT to any understanding of the studies in psychology is a knowledge of the different ways of looking at the facts of man which interest the psychologist. Unlike the subject matter of most sciences, the material with which psychology deals is at once the most immediately known and least open to concrete description. It is a knowledge of knowledge itself. In it man attempts to appraise himself and the ways he comes into contact with the outer world, to determine the impulses which may make him desire to know, to act, and to think. The very intimacy of the material with which it deals has made difficult the statement of what its aims may be. Whatever the reason, psychology is today and has been in the past very much at odds over the statement of the ends and methods it should pursue.

In the very early stages men were given to assuming the existence of very definite substances or beings as having real existence in the individual and as making possible his thoughts and directing his decisions and acts. This was called his mind. It was assumed by Plato to have been established in the body at birth by the supreme being or universal mind. Its more important thoughts were given it by the supreme mind and only the sources of the less important experiences were found in the senses. Aristotle gave more part in the determination of thought to the data of the senses but still found an essential determinant of the rational knowledge in the 'forms' that were in the individual from birth and were related to the highest form of the world. Popular theories made the mind more concrete, and even so distinguished a philosopher as Descartes opposed mind to the bodily processes, regarded it as much like a second man, and assigned it a seat in the pineal gland where it could receive knowledge from the senses and direct the movements of the body.

Succeeding thinkers modified this theory of Descartes. Spinoza suggested that body and mind were one and that one aspect seen from within constituted what we call consciousness, and the other aspect, which was turned outward where it could be seen by others, was the body. Berkeley denied the existence of any but the mental aspect and was content to say that God gave us the sensation which we ascribed to the outside world. Hume went farther in denying immediate existence to mind as well as to body. Hume would grant existence to nothing except the sensations which came we knew not from where and to ideas which were reproductions in fainter form of the sensations. He would assume nothing that he could not prove, and both objects in the outer world and mind as a receiving and controlling agent fell under the ban. Hume's position assumes the existence of experience alone without any definite object outside to be experienced, or any experiencing individual within. From that point on, attempts were made to determine what the nature of this experience was and the laws that governed the coming and going of sensations and ideas. This was the starting point for the modern scientific psychology.

The Precursors of Psychology in Physiology. — A second historic factor in determining the character of psychology was the increasing knowledge of physiology, especially the knowledge of the nervous system. Speculation about the relation between the mental processes and the body began with the early Greeks. Plato assigned the mind to the brain, Aristotle to the heart. The atomists thought that the mental processes were due to finer atoms which penetrated the pores between the larger atoms of the body and brought sensations into the body through the senses. Just before the experimental movement began in psychology, physiological research had been converging upon problems of sensation and the action of the nervous system. Johannes Müller had been active in both fields and Helmholtz and Hering had made lengthy investigations of sensation. Müller had covered most of the known facts concerning physiological psychology in his *Treatise on Physiology*. It was largely chance that what is now the subject matter of psychology was not incorporated in physiology. It was the chance that Wilhelm Wundt, who was for some years an assistant to Helmholtz in physiology, was given a place as professor of philosophy and carried his interest with him that was mainly responsible for the development of psychology, in the form that we know today. Wundt combined the physiology of sensation and of the nervous system with the more theoretical conclusions of the older men to give a new turn to psychology.

Wundt's Psychology. — The psychology of Wundt may be regarded as the starting point for the more recent developments. He was the first to develop a specifically psychological laboratory, although much work had been done before in the laboratories of other sciences on problems that were incorporated in psychology. He brought together a group of enthusiastic workers who carried his methods and the name psychology to many other institutions in different countries of the world. He also developed a point of view and a theoretical construction which was made the foundation of most of the modern schools. Some of the schools accepted his presuppositions in part; more developed in protest against them. They were as fruitful for the antagonisms they developed as for the advances in his system by its friends. Essentially Wundt's position may be said to be an analysis of the experiences which Hume made fundamental. He differed from Hume in accepting the sense organs and the physical world as the origin of the sense impressions. He also related all mental processes to the cortical structures and functions. His problem was one of determining the different forms of the components of experience and the laws which govern their coöperation.

The Structuralist School. — In America Wundt's work led directly to the development of the structuralist school. Wundt had always treated mental states as if they were real existences and had been interested in analyzing the total experience into small elementary units. He regarded experience or consciousness as made up of sensations in all of their manifold qualities, of feelings or affections to which he assigned three pairs of opposed qualities; and at times he added an immediate awareness of activity. In his earlier years he believed that the discharge of motor neurones, as a muscle was contracted, gave rise to a conscious experience. He assumed that there was no reason why activity of a sensory neurone alone should be accompanied by consciousness. The consciousness which attended the discharge of a motor impulse he called the innervation sense and thought that it gave an awareness of voluntary activity. Later in his life he abandoned this view. The acceptance of an innervation sense is interesting as showing Wundt's desire to analyze consciousness into elementary processes. Wundt did use many more general principles in the construction of his system. Most important of these was apperception, which was in part the equivalent of attention as an active force, in part it was a general voluntary control, and in part was the outcome of earlier experiences.

Titchener's Structuralism. — Titchener, one of Wundt's students who became prominent in America, changed Wundt's doctrine slightly and gave the system the name of structuralism. Titchener went back to the English tradition of Hume and the associationalists more definitely than did Wundt. Wundt tried to weaken the doctrine of complete control of recall through association as much as he could. He asserted that apperception was responsible always for the control of recall through association and that apperception was completely dominant in effecting certain combinations of ideas. Titchener was equally insistent on limiting the task of psychology to studying the structures or existential aspects of consciousness and he also limited the ways the elements could be put together to the older experiences that had been formed through older connections or associations. Titchener's elements were limited to sensations and the revived images, and to affections (pleasure and displeasure). He dealt with attending by seeking to determine the degrees of clearness of conscious processes. Titchener also made large use of association in explaining the way images were recalled and in the development of perception and other complicated processes. Any complex mental process could be explained as composed of simple sensations and images (reproduced sensations) united by the bonds of association.

Structures as Universal Elements. — No matter how complex the experience, all could be reduced to these simplest elements; and what is more characteristic of the school, solution of the complex, as of the simple problems of psychology, was complete when the analysis of consciousness into these simple elements was accomplished. Emotion was said to be primarily an affectively toned idea or sensation. The bodily processes which James had regarded as essential to the emotions were admitted to be present but were given a subordinate place in the total experience. Action was regarded as the effect upon the muscular responses of specific conscious processes, mainly the ideas of the end to be accomplished. The discussion of each of these states was devoted almost exclusively to determining what sensations and what affective processes preceded the act, and was very little interested in the functions they subserved or how the movements were aroused. Meaning and the reasoning processes, too, were explained by analysis into the types of images that were used and of the way the different images might be aroused by association. Function received very little space.

Introspection the Method of the Structuralist. — Almost the only method of psychology for the existential or structural school was introspection. As discovery of the elements of consciousness and of the way they were put together constituted the end of psychological investigation, the method of psychology must be introspection. As the individual who is conscious is the only observer of his conscious states, he alone could be relied upon for describing them. Since there could be only one observer and mental processes could not be recorded for future reference, introspection must be very careful and all possible rules should be set up to insure accuracy. These were given in detail for each problem. Instruments were required that should hold the external conditions as constant as possible. Approximate repetition of the conscious processes can be made probable, if not guaranteed, by adequate control of all of the stimuli. After all that can be done in objective precautions has been cared for, the final results must depend upon the skill and care of the observer.

The Reactions against Structuralism. — Until Titchener stated the problem of psychology by excluding from it all but the study of conscious processes, psychologists had been too much occupied with the problems themselves to be much concerned about how they should be defined. When the definition was used as an argument against experiments on animals and against applications of psychology, there was a vigorous reaction. The first of these was seen in the functionalist school and was comparatively mild. The functionalists were led by Dewey and Angell at the turn of the century, both at the University of Chicago. Functionalism as they presented it was an insistence that what mind or consciousness did should be considered by psychology as much or more than its mere content. They argued that if consciousness accomplished nothing for the animal, it would not have developed; and that a study of what these functions were and how they originated was quite as important as was the enumeration and description of the elementary mental processes. They had no quarrel with the work of the introspectionists and were quite willing to use introspection where it was helpful, but they did object to the limitations that the definitions and implications of structuralism placed upon the activities of the science of psychology.

The Contributions of the Functionalists. — The definite contributions of functionalism are not so readily formulated as those of the other schools, because, for the members of the school, definitions were subordinated to the solution of specific problems. In general the emphasis of the school was upon the whole situation rather than upon the elements. The first specific statement of the school was found in Dewey's "Reflex Arc Concept." In this article Dewey insisted that one could not understand a reflex if one thought of it as a movement aroused by a single sensation or sensory stimulus. On the contrary one must consider the purpose of the act, or if there were no purpose, the setting in which it occurred. One must consider also the effect of the response upon the stimulus and upon the organism in preparing for a new response. The reflex was a unit, not a combination of sensory stimulus and simple muscular response.

A second characteristic of the functionalist school was seen in the attitude towards the body-mind problem. Titchener followed Wundt in assuming that mind and body were distinct existences or substances. They were always found together although absolutely different in kind. They were also supposed not to act upon each other. A mere idea could not produce a chemical change, and a mere chemical change could not produce an idea. Still, the chemical changes in the cortex went on side by side with the ideas in the consciousness of the individual who possessed the cortex or was possessed by the cortex. Functionalism could not leave consciousness so unrelated to the body. Consciousness must have a function. No attempt was made to explain how this function was expressed, but it was insisted that cortex and body must in some way act upon consciousness or mind and be acted upon by it. The functionalists also experimented upon animals and upon men in ways which did not permit of introspection and with no reference to the conscious processes that might or might not be involved in the acts. Again they were quite ready to undertake investigations which might have a result that could be given a practical application. Functionalism was important more for the pleas it made for a wider interpretation of the functions and methods of psychology than for its own tenets.

Behaviorism. — The most vociferous of the schools of psychology of the second decade of the present century was behaviorism. Behaviorism is also a protest against the limitations of structuralism, but the protest resulted in a school that has become itself quite as dogmatic and arbitrary as ever was the school against which it protested. Various statements were made in the first decade of the century in favor of an objective method in psychology. The first specific formulation of the extreme form of behaviorism was by Max Meyer in 1911. Meyer argued that psychology should be restricted to the study of responses, and that this study should be from the outside without any use of introspection. All of the more complicated mental processes were explained in terms of reaction. Generalization, *e.g.*, was developed through making the same response to different stimuli or to different situations. Consciousness was not needed and could not be studied.

Watson's Behaviorism. — The most extreme form of behaviorism was suggested by Watson. Watson was a student of Dewey and Angell at Chicago and was early indoctrinated with the functionalist position. He had also devoted himself to experiments in animal psychology where introspection was clearly out of the question. He formulated his position in 1913 as opposed to the use of introspection under any circumstances, and expressed doubt as to whether consciousness had any place in the explanations offered by psychology. In his *Psychology from the Standpoint of a Behaviorist*, published in 1919, Watson went farther by denying the existence of consciousness altogether. The nearest approach to it is permitting the use of verbal reports upon various stimulations. These reports are limited to use in the ordinary linguistic responses, as in testing the accuracy of recall for words or nonsense syllables and in reporting on objects as actually seen. They are not to be used as a means of knowing what the inner experience of the individual may be. Language is just one of the features of the externally observed behavior of the individual.

For Behaviorism Thinking Is Mere Sub-Vocal Speech. — One striking contention of Watson is that one thinks only in words. The words are nothing more than the movements of the vocal organs, which may be so repressed that the observers have no indication of them. Movements of the tongue and larynx are frequently being made when no sound is uttered. Watson insists that whenever one thinks, these movements are responsible for the results. Records that have been made of the tongue movements indicate that subjects do think when no movement can be detected. More interesting in the theory is the question of what value can be assigned to the movements if there is no consciousness to record them and no evidence that the slight responses can lead to action of an overt type. They cannot be shown to be present and it seems that if present they would have no definite function. A similar question might be raised as to the possible function of emotion. Emotion, too, was reduced to mere bodily responses with no conscious accompaniment. No connection was traced between the expressions in the emotion and the observed movements of the individual.

The Methods of Behaviorism. — The method for behaviorism that seemed least objectionable was the application of the conditioned reflex adapted from Pawlow (see pages 316 f.). This permitted the study of learning in all of its forms without the use of words and without assuming consciousness. The method became the more important since Watson assumed in his later works that heredity was not a factor in determining the activities of man. Watson asserted in his *Behaviorism* that he could take children from parents of the most diverse intelligence and train them so that they should have the qualities he desired. It should be said that emphasis on the importance of the conditioned reflex was largely formal. He was interested only in finding a method that could be used which need make no reference to consciousness. Very few experiments have been made to demonstrate even the possibility of conditioning reflexes in the human species and they mostly not by behaviorists. While behaviorism had wide acceptance during the first two decades after it was proposed, it seems now to be waning in importance. It still receives adherence from many American psychologists.

The Gestalt School. — First appearing in its latest form at about the same time as behaviorism, a rapidly growing claimant for acceptance is the Gestalt school. The Gestalt school is an outgrowth of phases of psychological theory that have long been recognized. We have mentioned several of its aspects in Chapter XIII. The beginnings of the movement can be seen in the work of Brentano in opposing the meaning of an idea to its structure or content. It also recognizes the importance of the total form or whole of an experience as opposed to the elements. Recognition of the importance of the whole or of the form as the expression of the whole, began with a statement by Mach that the form of any geometrical figure is something more than the lines that compose it. Von Ehrenfels in 1890 extended this idea to make Gestalt, the German word for form, a very definite existence added to any figure. Not merely visual figures, but objects as they are presented to any sense have this characteristic which is added to the mere elements and gives them their true importance. Von Ehrenfels pointed out that a melody was still the same melody when transposed into the minor key although no one of the notes was the same in the two keys. The melody cannot be present without notes, but the notes are not identical with the melody. The Gestalt is the essential characteristic of the whole and is present in revived experiences, memories, and imagination as well as in perception.

The Modern Gestalt School. — In 1910 Max Wertheimer was experimenting on the illusions of movement produced when two lines are exposed successively a little distance apart and came to the conclusion that the apparent movement of the line which resulted was a new something added to the elements. (See page 460.) More truly he thought of it as a new experience which developed on the occasion of the stimulus of the two lines but was not dependent upon them. To this character, too, he applied the name Gestalt. During the war Köhler was interned on the Island of Teneriffe where he had gone in 1914 to experiment with apes. In the results with the apes he found evidence that they too developed certain complete notions as units which could be applied at once to the solution of problems. He called these insights and identified the name Gestalt with the insight. (See page 314.)

The modern form of the Gestalt doctrine can be traced to the two works of Wertheimer and Köhler. The most important difference between the doctrine of von Ehrenfels and the more recent members of the school lies in the belief of the more recent men that the Gestalt is not at all dependent upon the elements that compose it. On the contrary the whole determines the parts, and the form gives existence to the elements. The Gestalt is self-determining and self-contained.

What Is a Gestalt? — To give a definition or indication of what Gestalt means, that will satisfy the upholders of the doctrine and be enlightening to the individual who is not already indoctrinated, is not easy. In some ways it is opposed to the mental content as a structure is opposed to meaning. At least meaning is a phase of the total experience in connection with a percept that is important for the individual and it is not the structure or image. One is concerned with what a smell means as a possible beginning of a conflagration, or as indicative of an approaching meal rather than with the elements that constitute the experience. Again Gestalt is like the object as opposed to the purely mental image or sensation. In everyday life we deal with things and are not at all interested in the mental mechanism that may be regarded as permitting objects to be communicated to us. Objects are taken as wholes. We regard as a whole at one time what at another is a part of a larger whole. Whether or not it is also part of a larger unit, the thing dealt with when used becomes for us a whole. When treated as a whole there is no thought of the parts. While the Gestalt is thought of as mental not physical, it does correspond somewhat roughly to what the man in the street regards as a single object. In brief, a Gestalt is something about the whole of a given experience which constitutes its essential characteristic. This essential is not very different from its meaning, and it is also quite like the factors that make an experience an object and not a vague experience.

Instances of Gestalt. — It is easier to show what a Gestalt is by giving instances than by abstract definitions. As already stated the melody is a Gestalt when considered apart from the notes that give the occasion for it. A geometrical figure is or contains a Gestalt. These may be graded in their completeness. The circle is the most perfect Gestalt, a square is next, and then an equilateral triangle. Any physical object is a Gestalt or occasions a Gestalt. The simpler the object, the more perfect it is as a Gestalt. Motion is a Gestalt that may be presented to eye or skin. Distances, rhythms, space relations, and general ideas are also Gestalten. A Gestalt is present only when there is some common principle of unity in the mass of experiences. Otherwise only the elements exist. That is what Wertheimer has called a mere bundle in which the parts are held together only by 'and-connections.' They are not unified or integrated.

The Determinates of Gestalten. — The active forces behind the Gestalt are found in the interactions of the nervous system. Connected with each Gestalt is always a group of nervous structures whose action is to be explained from interacting forces. These also form unitary wholes which are related as interacting physical forces. Within each unit are found stresses which tend to resolve themselves in a way to give the least strain. The unit is determined by a balancing of the forces within it. The physical laws of interaction, especially the laws of thermodynamics, are asserted to hold for the Gestalt and for the relations of the nerve structures which are the substrate of the Gestalt. Details cannot of course be given as to how much depends upon the nerve elements themselves and their interaction and how much upon actual physical tensions or how far the two are to be regarded as the same. It is insisted that the laws of Gestalt are the laws of the nervous interactions and that for practical purposes the two may be identified. In both, the wider laws of interaction dominate the effects of the separate elements.

Gestalt in Opposition to the Other Schools. — Gestalt psychology is opposed to behaviorism, since it deals with conscious processes. Again the conditioned reflex, which Watson makes the fundamental method of explaining learning, is almost as distinctly an element as is a sensation. The behavioristic theory builds its explanation of human behavior by putting together single responses with little reference to wider wholes. The Gestalt position is that behavior is to be referred to interacting wholes in the nervous system, just as experience is to be referred to organized wholes. On both counts behaviorism offers no appeal to Gestalt. Its quarrel with structuralism is more fundamental, since structuralism is the main advocate of the building of mental processes from elements and in the use of associations to explain the recall and combination of the elements. In the animal field the Gestalt school brings vigorous objection to the use of the trial and error hypothesis. Solving problems is asserted to be through insight. This means as was said that the animal sees at once what the solution is and then proceeds to put it into execution. The insight has certain similarities with the Gestalt since it presents itself as a whole and has no explanation in the antecedent acts.

The Purposive School. — Among the less generally accepted positions is the hormic or purposive theory advocated by McDougall. This is in direct descent from Aristotle. Aristotle asserted that all acts of living beings were directed by what he called the form. The form is a force like mind and of divine origin which makes the living body grow according to a definite plan and gives a purpose to the activities of the organism as a whole. McDougall has accepted this view with modifications. For him mental life would be meaningless if it did not have aims. They give direction to each separate act and make it part of a wider pattern. This final direction or goal finds an expression in each act and each wish. Each of the minor activities can be understood only in the light of these controlling purposes which are regarded as innate.

Freudian Theory. — One might mention one theory that bears upon normal psychology, which has had its development altogether in the field of abnormal psychology although it has not found wide application in the more general treatises. Freud's theory has already been referred to in connection with dreams. In its more general outlines the theory assumes that most of the determinants of mental life are derived from the unconscious. The unconscious is made up of experiences which have been driven out of the upper consciousness and which are still active below the level of which we have direct knowledge. In addition to being a receptacle for forgotten memories or for bits of life which are to be directly recalled, the unconscious is a second individual with desires of its own which seeks to force certain primitively absorbing ideas upon the conscious self. These appealing ideas or experiences are mostly of a sexual nature, and the unconscious endeavors to compel the reluctant upper consciousness to contemplate them.

The essential characteristic of the Freudian theory is that it places most of the actual determinants of the consciousness which we know in the unconscious. There is really no satisfactory way of discovering these essential causes. They manifest themselves in dreams, but only in the most fragmentary way. They explain the errors in some of our thinking. They may be approached at times in hypnosis, but both in dreams and in hypnosis one can never be sure that what pretends to be the real experience or the determinants of experience is what it seems. Even there it veils itself behind symbols and various deformations of the real truth. One can discover the clew to their real nature only by applying certain rules that the psychoanalyst believes he has discovered from dealing with the mentally disturbed. These rules cannot well be confirmed objectively because what the symbol is supposed to represent can by definition never be fully discovered. The theory has a greater value for suggestion than for demonstration. The psychoanalytic theory has few points of contacts with the suggestions of other schools since the points of view are too different. Behaviorism is quite as much opposed to an unconscious as to a conscious. The Gestalt school has no occasion to express itself on the point. The older schools have never taken the unconscious very seriously, — the assumption is too remote from observed fact.

One could multiply schools more or less indefinitely by stressing minor divergences, but this list will suffice to give an idea of the wide diversity of view points at present. There is no possibility of harmonizing all the different points of view. It is equally futile to endeavor to prove that one is true and the others false. Each represents a possible attitude towards the facts of mental life. Each in its extreme form is one-sided. Most of the positive statements of each of the theories can be justified. The mutually contradictory negative statements must be ignored since they mutually nullify each other. If one understands each, one has a better rounded idea of the complexities of the psychological principles. It is not necessary to believe if one understands. Reservation of judgment on some points is still necessary. What can be accepted will be enlightening.

In addition to the members of the distinctive schools are many psychologists who believe that fact is more important than theory; that the one essential to progress of the science is the collection of facts without prejudice of theoretical standpoint. These facts assuredly must be organized into general statements, but the organization must be one that is peculiarly suited to each set of facts. They cannot be prescribed in advance by an over-theory or school. The men who find themselves outside of the narrow schools often have leanings in the direction of one school or another. One phase of their teachings will be more in harmony with behaviorism, others more influenced by the Gestalt school, but they are not confined in advance to one set of conclusions. The facts determine the formulation, not a preconceived formulation the facts. From the open-minded psychologists of this middle group, advances in appreciation and in theory are more likely to come than from the members of the more fixed schools. To know and appreciate the good points of the different schools is essential to an understanding of modern psychology. To attain this end it is not necessary to accept the dogmas of any school as true, even after a careful examination to decide which is the most probable.

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